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Survey and Performance Evaluation of Multiple Access Schemes for Next-Generation Wireless Communication Systems

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ABSTRACT Mobile communication systems are always in continuous evolution due to the demands of the end-users using this technology. Therefore, before the possible launch of 5G, some technologies have opened the way to the new mobile communication system. The need for technologies that provide more comfort to users has led to the construction of complex communication systems that were only science fiction decades ago. The information society in which we are now immersed has been the result of constant progress over time. In this paper, a survey of multiple access schemes for next-generation wireless communication systems is presented. Multiple access schemes are reviewed for possible use in next-generation wireless communication systems such as orthogonal multiple access (OMA), non-orthogonal multiple access (NOMA), and delta-orthogonal multiple access (D-OMA), etc. General comparisons of 1G to 6G are presented. Different types of OMA are explained, and then orthogonal frequency division multiple access (OFDMA) is chosen as an example of the OMA scheme to compare with NOMA and D-OMA. There are two types of NOMA: power-domain and code-domain, which are discussed and compared. Simulation results are presented, and a comparison among different access schemes is provided.

INDEX TERMS D-OMA, Multiple access schemes, next-generation wireless communication systems, NOMA, OFDMA, OMA

I. INTRODUCTION

A multiple access scheme is a leading technology for distinguishing various wireless systems from first-generation (1G) to sixth generation (6G). The evolution of 1G to 6G is presented in Fig. 1. Frequency division multiple access (FDMA), time division multiple access (TDMA), code division multiple access (CDMA), and orthogonal frequency division multiple access (OFDMA) have been used in 1G, 2G, 3G, 4G, respectively. These are orthogonal multiple access (OMA) techniques. Various users are assigned in an orthogonal way in these multiple access systems, either time, code, or frequency domain, to prevent or mitigate inter-user interference. In OMA, the data carrying signals of the users can be conveniently isolated by deploying reasonably cost-efficient receivers at low complexity. However, OMA can support limited users because of orthogonal resources [1]. With the aim of supporting more users non-orthogonal multiple access (NOMA) is proposed. To separate the non-orthogonal signals, complexity in the receiver is increased in NOMA [2]. Recently, delta-orthogonal multiple access (D-OMA) has been suggested in 6G systems for massive access [3].

NOMA, OMA, and D-OMA have been attracted a significant amount of attention in recent years by researchers who have aimed to fulfill the wireless communication criteria of the next generation. The research trend covers numerous subjects, such as various performance analysis methods, fairness analysis, code and power domain, and user pairing. At this point, a detailed understanding of the current research state of NOMA,

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TABLE I
DIFFERENCE BETWEEN OUR SURVEY AND OTHER SURVEY PAPERS OF SIMILAR NATURE

Survey	Method	Technique	Domain
Riazul Islam et. al [4]	NOMA	5G	Power allocation
Mohammad karimi et. al [5]	S-NOMA	5G	Code domain
Riazul Islam et. al [6]	NOMA, OFDMA	5G	Downlink, power domain
Wang et. al [7]	TDMA, FDMA, CDMA, IDMA, NOMA	3GPP	Delay-sensitive applications
Ruby et. al [8]	NOMA	5G	Power allocation
Bhaga et. al [9]	OFDMA, SC-FDMA	LTE	Uplink, downlink
Sharma et. al [10]	SDMA	5G	Power allocation
Our Survey	FDMA, TDMA, CDMA. SCMA, NOMA, OMA, D-OMA	1G, 2G, 3G, 4G, 5G, 6G	Power allocation, code domain, power domain, uplink, downlink

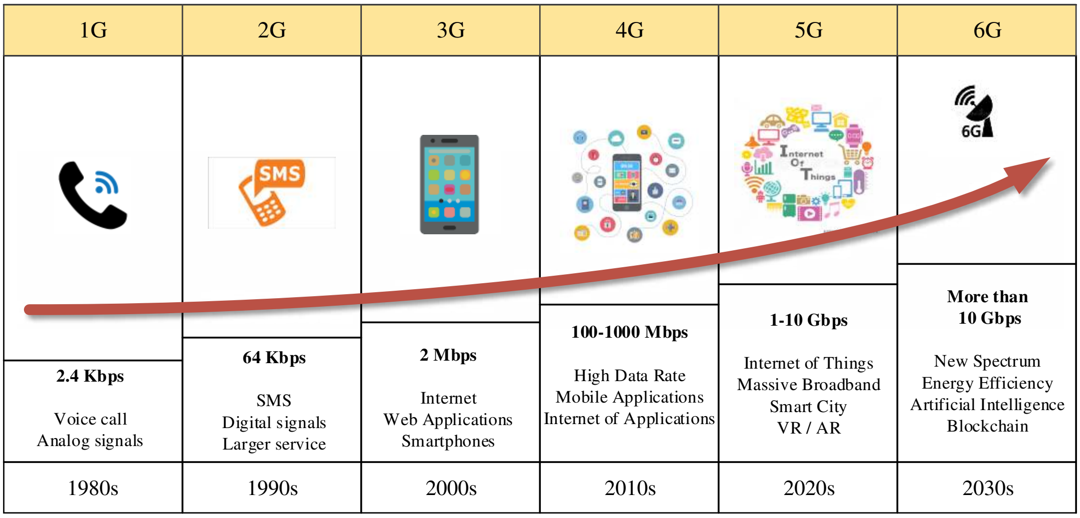

FIGURE 1. The evolution of 1G to 6G.

OMA, and D-OMA in wireless communication systems of the next century is enormously helpful for researchers who would like to do more in this area. In this article, a survey of multiple access schemes for next-generation wireless communication systems is presented. TABLE I further explains the difference between our survey and other survey papers. The contributions of this paper to the literature are outlined as follows:

- General comparisons of 1G to 6G is presented.
- OMA, NOMA, and D-OMA are reviewed.
- Different types of OMA such as FDMA, TDMA, CDMA, and OFDMA are examined. As an example of the OMA scheme, OFDMA is selected for comparison with other techniques.
- NOMA in the power domain and NOMA in the code domain are also studied. D-OMA scheme is described.
- Simulation results are presented, and a comparison among different access schemes in next-generation wireless communication systems is provided.

The remainder of the article is arranged as follows: multiple access techniques are illustrated in Section II. Section III presents comparisons and simulation results. Finally, the conclusion is drawn in Section IV.

II. MULTIPLE ACCESS TECHNIQUE

Multiple access techniques are highly relevant since they allow users to access the means of communication and are responsible for providing service to a specific number of users simultaneously, those connected to the same medium. Therefore, multiple access is done by multiplexing users by sharing resources in time, frequency, or code. This implies that users use the same resource in an organized way, mitigating interference with other users. A review of multiple access technologies is presented in Fig. 2. Multiple access technology can be classified as OMA, NOMA, and D-OMA. FDMA, TDMA [11], CDMA [12], OFDMA [13] are OMA schemes. NOMA scheme can be divided into two types: power-domain [4-35] and code-domain [40]-[73]. The code-domain NOMA schemes include interleave division multiple access (IDMA) [74], low-density spreading (LDS) CDMA [75], sparse code multiple access (SCMA) [76-92], pattern division multiple access (PDMA) [93], multi-user shared access (MUSA) [94], etc.

A. OMA

Conventional OMA access techniques allow multiple users to use resources orthogonally and share system resources simultaneously by time division, frequency, or code [3]. Thus, there is nominal interference between adjacent blocks allowing signal detection to be reasonably accessible with increasing complexity at the receiver. There are various OMA techniques, depending on how they divide the resources of the medium through which information is

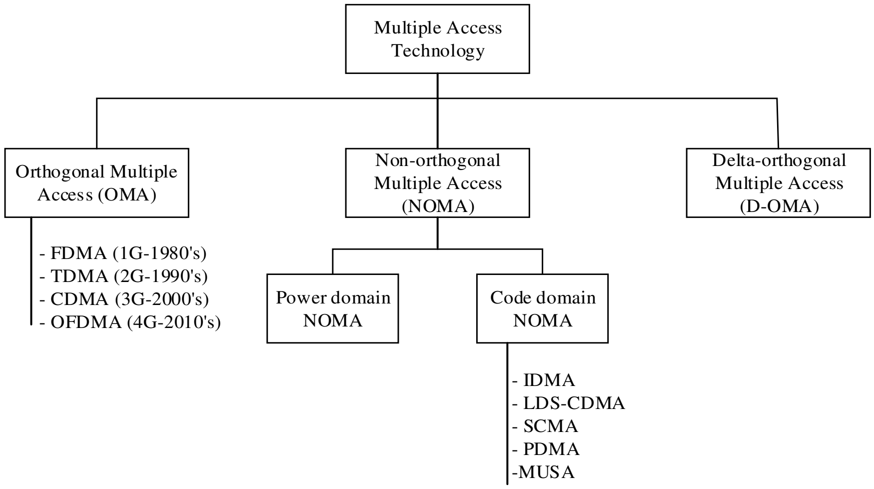

FIGURE 2. **A review on multiple access technologies.**

transmitted. The main OMA techniques are TDMA, CDMA, FDMA, and OFDMA, which are described below.

1) OFDMA

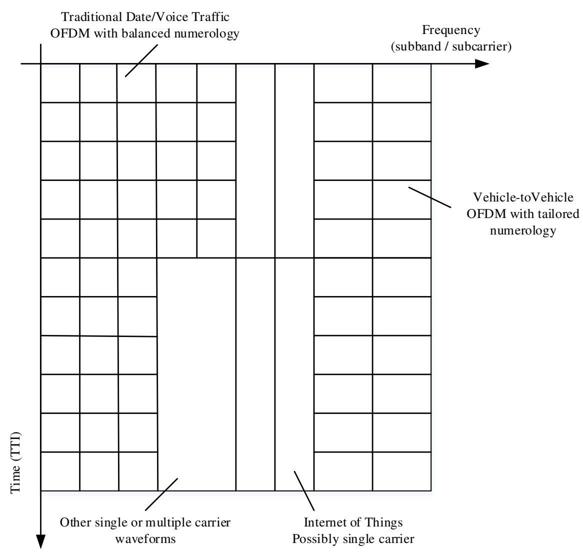

FIGURE 3. **Example of OFDMA.**

Instead of the data being transmitted as a single transmission, orthogonal frequency division multiplexing (OFDM) splits the data into parallel sub-streams. It sends each sub-stream to a different frequency, well-known as a subcarrier. A vast number of carriers are used by OFDM, each with low bitrate data. It provides a high degree of spectral efficiency and is very resistant to selective fading, inter-symbol interference (ISI), and multipath effects. One of OFDM's key benefits is that it is more resistant than single carrier systems to selective fading. It divides the complete channel into several narrowband signals that each has sub-channels as flat fading. Though the OFDM idea was developed in the 1960s, OFDM's most significant impetus was reducing the prices of integrated circuits and the possibility of using the fast Fourier transform. OFDM is a multicarrier modulation (MCM) and frequency division multiplexing (FDM) based technique. It is possible to think of OFDM as a method for modulation or multiplexing. The elementary idea behind multicarrier modulation is to split the bandwidth of the signals into parallel subcarriers or narrow bands of the total bandwidth [13]. Fig. 3 shows an example of the OFDMA structure.

In the digital domain, the OFDM symbol is formed before transmission. Then, common digital modulations such as BPSK, 16QAM are applied to it (5G intends to use modulations up to 256QAM). Finally, this data flow is divided into N parallel flows, which become an OFDM symbol. Thus, an OFDM symbol is made up of several samples of different information flows.

$$X_k = \sum_{n=0}^{N-1} a_n e^{\frac{j2\pi kn}{N}}, \tag{1}$$

where a_n denotes the data symbol in the nth subcarrier [95]. The equation is equivalent to the nth point of the discrete inverse Fourier transform (IDTF). The spacing of the subcarriers and the frequency are chosen so that the orthogonality criterion is fully met. Orthogonality means that the average value of the multiplication of two signals at time T is zero. This criterion deals with the equation:

$$\frac{1}{T}\int_T x(t)\,y(t)dt = 0. \tag{2}$$

2) TDMA

This multiple access method is based on the time-division multiplexing (TDM) scheme in which a time slot is allocated to each data stream. In the case of TDMA, each data stream corresponds to a user connected to the shared medium. In mobile communications, TDMA is used in almost all second generation (2G) schemes, highlighting global system for mobile communications (GSM). The equation below further explains the TDMA [96]

$$\eta_a = \left(\frac{\tau M_t}{T_f}\right)\left(\frac{B_u N_u}{B_w}\right), \tag{3}$$

where η_a is spectral efficiency, τ is time slot length that

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carries data, T_f is period of frames, M_t is the number of time slots per frame, B_u is an individual user's bandwidth during his or her time slot, N_u is the user's number in the system sharing the same time slot, but having access to various frequency sub-bands.

3) CDMA

While in TDMA and FDMA, the resources are divided temporarily, assigning a time slot or a frequency band only to a specific user. In CDMA, all users can transmit concurrently and in an identical frequency band. It is attained by allocating each user a code that differentiates them from the rest. The most common CDMA model is direct sequence spread spectrum CDMA (DS-CDMA). The code assigned to each user is a pseudorandom number (PN) sequence that multiplies the signal corresponding to a symbol and user. The sequence breaks into chips whose duration is much less than the symbol time. The result is a signal with a noisy appearance and an expanded spectrum. When the received power P_s of all these signals is identical, the wanted signals will be interfered by $m-1$ equal-power CDMA signals. In this manner, the RF has a carrier-to-interference ratio (C/I (dBm)) = 10log(1/m), which is a negative number known as "self-impedance" brought about by the other $m-1$ carriers that at the same time involve a similar transfer speed as the m^{th} wanted carrier. The probability of error (P_e) brought about by the self-interference of the m concurrent equivalent force got signals is given by:

$$P_e = \frac{1}{2} erfc \sqrt{2\left(\frac{1}{m-1}\right)\left(\frac{f_c}{f_b}\right)}, \quad (4)$$

where m indicates the user's number, f_c is the bit rate of pseudo-random code, and f_b is the bit rate of the data signal. The ratio (f_c/f_b) denotes the spread of the spectrum. CDMA fixes the timing issues associated with TDMA and FDMA but is more vulnerable to the near-far problem. The 2G CDMA-One system and most 3G mobile phone systems like CDMA2000 or UMTS incorporate CDMA.

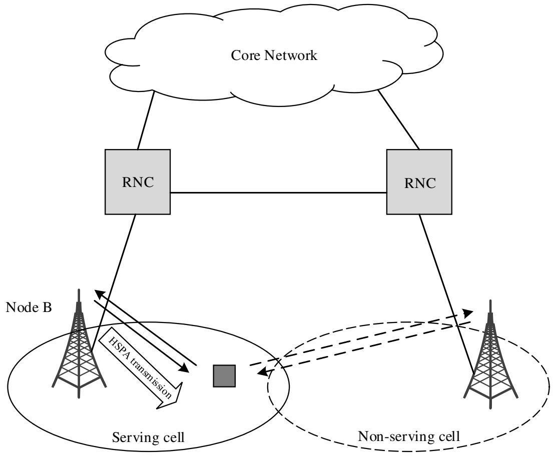

FIGURE 4. **CDMA workflow.**

Fig. 4 demonstrates CDMA workflow. The radio network controller (RNC) manages and controls radio resources in the Node Bs. RNC is equivalent to the base station controller (BSC) in the GSM.

4) FDMA

For this access to the medium, the bandwidth is divided among multiple users, corresponding to each of them only one or more subcarriers. OFDMA is the version of FDMA in which the subcarriers are orthogonal to each other and is an adaptation of the OFDM modulation technique for multiple access. Single carrier FDMA (SC-FDMA) is the pre-DFT encoded version of FDMA. Although FDMA techniques have the disadvantage of demanding frequency synchronization, ingenious implementations such as OFDMA and SC-FDMA have numerous benefits over TDMA or CDMA, such as multipath robustness or the elimination of costly time-domain equalization for channels with long temporal dispersions like wireless, replacing it with a much simpler frequency equalization. It can be highlighted that the ease of distribution of resources in frequency according to channel conditions, very useful in frequency selective channels such as wireless. For this reason, OFDMA and SC-FDMA are the techniques of choice for the physical layer of the radio interface of the new standard for mobile communications long-term evolution (LTE) for UMTS. Fig. 5 illustrates differences between CDMA, FDMA, and TDMA.

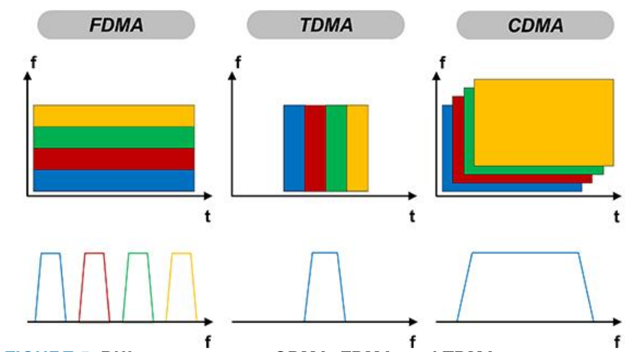

FIGURE 5. **Differences among CDMA, FDMA, and TDMA.**

B. NOMA

NOMA is the multiple access method that permits users to use resources concurrently in a non-orthogonal way on a subcarrier by transmitting information on the same frequency simultaneously with diverse power levels or through code allocation [14-15]. NOMA presents a significant impact on the decrease in latency during simultaneous transmission. This means that the resource is better used by using all the bandwidth and thus improving the spectral efficiency. In recent times, for fifth generation (5G) cellular networks, NOMA schemes have gained considerable interest. The fundamental explanation for the adoption of NOMA in 6G is its ability to support numerous users while utilizing identical time and frequency resources. NOMA utilizes overlay encoding in the sender and successive interference cancellation (SIC) in the destination to multiplex users in the power domain. As illustrated in Fig. 6, the base station (BS) transmits overlapping signals to two users, with the first user getting a more significant channel gain than the second user. A survey of the NOMA scheme is presented in TABLE II.

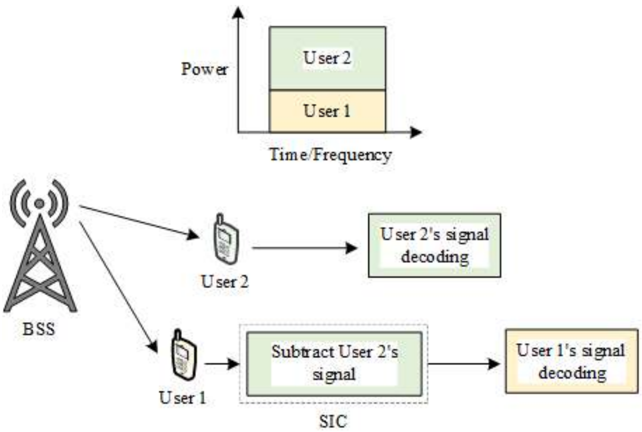

FIGURE 6. NOMA workflow.

There are numerous NOMA methods, which can be separated into two primary forms. Fig. 2 contains a basic classification of NOMA schemes that exist. In contrast to a NOMA power-domain that reaches power domain multiplexing, code-domain NOMA reaches code-domain multiplexing. Like the CDMA systems, the NOMA coding domain shares all available resources (time/frequency). Code domain NOMA, contrariwise, utilizes a user-specific sequence that is fragmented or non-orthogonal and has a low correlation coefficient cross-relation. Code domain NOMA can also be classified into a few categories: low-density CDMA (LDS-CDMA), LDS-OFDM, and SCMA. This is the only class that can break into many different classes. LDS-CDMA allows limiting the influence of interference on any chip of fundamental CDMA systems by utilizing a low-density spreading sequence. LDS-OFDM can be considered the combined LDS-CDMA and OFDM, with symbols spread over low-density propagation sequences first and with the resulting chips sent on various subcarriers. SCMA is a modern LDS-CDMA-based NOMA code-domain technique. Unlike LDS-CDMA, data bits can be mapped directly into different sparse codewords since they combine bit mapping and bit spreading. SCMA facilitates a low-strength reception technology and increases productivity compared to LDS-CDMA. Some of the other access methods that are closely linked to NOMA include PDMA and multiple-access spatial division (SDMA) are also available. In different domains, PDMA can be performed. PDMA first maximizes diversity on the transmitter side and reduces overlaps among multiple users to the minimum for the creation of non-orthogonal patterns. The multiplexing occurs in the code domain, in the spatial domain, or a mixture of it. For SDMA, it is based on the basic CDMA systems. The working principle SDMA identifies various users by utilizing user-specific channel impulses rather than user-specific spread sequences.

NOMA integrates various wireless communication methods such as multiple input multiple output (MIMO), cooperative communications, space-time coding, beamforming, and network coding [18-19]. It should be stated that the usage of NOMA technologies is not confined to the use of different multiplexing techniques. OFDM's NOMA application scenario is considered because of the benefits and extensive use of OFDM in today's wireless communication systems.

Since the power domain users are multiplexed, the power allocation feature in NOMA is strengthened over OMA. Interference monitoring, rate distribution, and even user entry is all influenced by the power distribution. Power allocation in NOMA specifies the user channel parameters, the availability of CSI, QoS specifications, total power constraints, and system intent. An incorrect assignment of power results in an unequal distribution of the rates between users and origins a system outage as SIC can fail. Various performance measures for power allocation include the number of users admitted, amount rate, fairness of user, probability of outage, and overall energy consumption. Therefore, the goal in NOMA should be to achieve either more users and a higher amount rate and equal power allocation under a minimum power consumption. NOMA distributes more power to users with lower channel gains with the purpose of guaranteed user fairness. Due to an additional overhead system for coordination of channel feedback and error propagation, the joint application of NOMA to all users is not feasible. The concept of a user pairing has therefore arisen, with cell users split into different clusters and NOMA used for each cluster. A NOMA system relies heavily on user pairing as well as power distribution. In NOMA, the distribution of resources attempts to classify the users to be paired and the power to be assigned to each user by each cluster. A detailed search for all possible user pairs and a computationally complex allocation of power will achieve optimal NOMA resources allocation.

In downlink NOMA, decoding of signals in UEs is performed in the order of decreasing ratio values $|h_i|^2$ Under this criterion, it is assumed that the UE-i can eliminate inter-user interference from UE-j si $|h_j|^2 < |h_i|^2$. In the case of 2 users, if $|h_1|^2 > |h_2|^2$ the UE-2 decodes the signal first, so there is no interference cancellation. For its part, the UE-1 decodes the signal x_2 and the subtraction of the received signal y_1, and then decodes x_1 without the interference of the UE-2. In the ideal case of lack of decoding errors, the spectral performances of each user will be:

$$R_1(b/s/Hz) = \log_2\left(1 + \frac{p_1|h_1|^2}{N_1}\right), \quad (5)$$

$$R_2(b/s/Hz) = \log_2\left(1 + \frac{p_2|h_2|^2}{p_1|h_2|^2 + N_2}\right), \quad (6)$$

where p_i and N_i denote the transmit power and Gaussian noise power and inter-cell interference by the i-th user, respectively.

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TABLE II
A SURVEY OF NOMA SCHEMES

No	NOMA techniques	Company	Full Form	Uplink (UL)/ Downlink (DL)
1	Power-domain NOMA [4-35]	DCM	Power-domain non-orthogonal multiple access	UL/DL
2	SCMA [76-92]	Huawei	Sparce code multiple access	UL/DL
3	PDMA [93]	CATT	Pattern division multiple access	UL/DL
4	MUSA [94]	ZTE	Multi-user shared access	UL/DL
5	LSSA [99]	ETRI	Low code rate and signature based shared access	UL
6	RSMA [100-102]	Qualcomm	Resource spread multiple access	UL
7	IGMA [103]	Samsung	Inter-leave grid multiple access	UL/DL
8	IDMA [74], [104]	Nokia	Interleave division multiple access	UL
9	NCMA [105]	LGE	Non-orthogonal coded multiple access	UL
10	NOCA [106]	Nokia	Non-orthogonal coded access	UL
11	GOCA [107]	MTK	Group orthogonal multiple access	UL
12	RDMA [107]	MTK	Repetition division multiple access	UL
13	LDS-SVE [75], [108]	Fujitsu	Low density spreading-signature vector extension	UL/DL
14	FDS [109]	Intel	Frequency domain spreading	UL
15	LCRS [110]	Intel	Low code rate spreading	UL

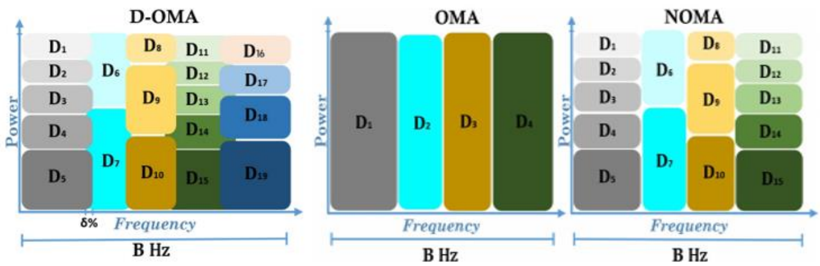

FIGURE 7. **D-OMA, NOMA and OMA frequencies.**

a) Advantages of NOMA

NOMA presents promising benefits in its application in wireless networks in new generation technologies, which show a high demand for simultaneously connected users. The benefits of using NOMA in wireless networks are high spectral efficiency, adequate power allocation, low latency, massive connectivity, good compatibility, etc.

b) Disadvantages of NOMA

The disadvantages of NOMA are dynamic user pairing, impact of transmission distortion, resource allocation, etc.

1) POWER DOMAIN NOMA

Power domain NOMA, served simultaneously by multiple users, channel frequency or code spreading, and multiple access is implemented by multiplexing the power domain, which means that various power levels are allocated to various users. A single frequency channel in the power domain NOMA is allocated to several users in the same cell and therefore better connectivity is possible compared to OMA. The bandwidth available is not split between different users and each user can transmit the entire available spectrum for high system performance. Moreover, multiple users are served simultaneously, and no users are required to submit scheduling requests from the base station to ensure low transmission latency. Power domain NOMA also supports existing OMA systems, e.g., TDMA and FDMA; existing wireless networks can be easily adopted.

2) CODE DOMAIN NOMA

The signals can be superimposed together in the power domain NOMA by several users. The benefit is that the interference cancelation technology is better but still complicated [18]. So, the most preferred choice is a NOMA code domain. The NOMA code domain multiplexes users by using specific sequences with sparse, low-density, and low cross-correlation properties for each user.

2.1) IDMA

The interleave division multiple access (IDMA) is considered a potential applicant in the code domain NOMA. It can be regarded as a particular case of code division multiple access direct sequences. In IDMA, specific sequences are not used to distinguish users instead of the code division multiple access. Instead, the entire bandwidth is for forwarding the error correction code, resulting in a shallow code rate than the code division multiple access systems. In addition, user-specific interleavers in IDMA are also used as a unique feature for separating users [74].

2.2) LDS-CDMA

Recently significant attention has been paid to the Low Density Signature Code Division Multiple Access (LDS-CDMA) [75]. The main idea of the LSD-CDMA is that only a few non-zero elements in the spreading signature have every data symbol spread over a limited number of chips. Therefore, only a small number of other data symbols interfere with every user to ensure that LDS-CDMA can be used as an overload. However, efficient multi-user detection must be further addressed to make LDS-CDMA a successful candidate for 6G air interfaces.

2.3) SCMA

The Sparse Code Multiple Access (SCMA) [76] is a well-known code domain NOMA technique considered for 6G, with a limited number of users permitting each other to intervene. However, a unique, sparse, multidimensional, and complex codebook is assigned to each user. In SCMA, the codebooks are used to simultaneously recognize multiple users to spread the modulated symbols from the users over the allocated resources. SCMA has certain features that can be listed below.

- Bits are mapped directly from the predefined multidimensional codebook to the multidimensional codeword. Users are differentiated using code words, and therefore multiple access is achieved.
- MPA Multiuser Detection Scheme in moderately complex recipients is used.

2.4) PDMA

The characteristic that identifies a NOMA scheme as a PDMA is that non-orthogonal patterns are present in LDs-CDMA [26] rather than spread sequences. PDMA patterns are used to map the data transferred to a group of resources, whether time, frequency, space resource, or any combination of such resources. Compared to the distribution code, the concept of PDMA patterns could be more widely understood. In the general case, a PDMA pattern matrix element can be either filled with binary numbers or weighed by the power scaling and shifting of phase.

2.5) MUSA

A further key feature is MUSA [94], along with the overloading, grant-free access. This strategy allows every user to choose freely from the large cardinality of their spillover sequence, which fails to coordinate the resource base. MUSA can reduce overhead signaling and transmission delays caused by conventional grant-based transmissions by adopting grant-free access. It reduces MUSA's device energy consumption, and thus the uplink transmission is suggested by MUSA. A short length and low cross-correlation of MUSA spreading sequences should be required to support many free users and minimize the impact of a user collision.

C. D-OMA

The high complexity and increased power usage on receivers are two significant impediments to implementing in-band NOMA clusters on a large scale. D-OMA is proposed to solve these problems to fulfill the requirements for 6G. D-OMA overlaps sub-bands of NOMA clusters. Let δ be the overlapping percentage. When δ is zero, it is the power-domain NOMA. Due to overlapping NOMA clusters, inter-cluster interference (ICI) may arise. Therefore, if non-overlapping massive in-band NOMA clustering is utilized, the size of each cluster should be reduced so that the total of intra-NOMA interference (INI) and ICI is equal to INI. Spectral efficiency obtained by a large in-band NOMA cluster is retained by integrating more clusters into the same allocated total spectrum (Fig. 7). The degree of complexity and power consumption specifications on various NOMA terminal systems would be greatly decreased at the same time by reducing sizes of different NOMA clusters, thus maintaining the same efficiency restrictions as before.

A high level of cluster overlap creates noise on the curves, especially at high power costs. The suggested scheme in [3] could apply to both uplink and downlink transmissions. Still, it may be challenging to use D-OMA at the uplink as the need to share control signals between the cooperating APs and terminal devices increases. Compared to a large NOMA, the D-OMA efficiency depends on the scale and the overlap between the clusters and the spectrum. With D-OMA, compared to the massive in-band NOMA, it is possible to reduce cluster size (and the complexity of SIC) while delivering nearly equivalent efficiency.

Designing SIC processes for NOMA receivers presents a new challenge. The devices are ordered in the traditional NOMA from the same AP point of view, and the SIC is obtained accordingly. D-OMA cannot use the same SIC technology because many cooperation APs will order different devices differently. In addition, some suboptimal, low-complexity methods are sufficient to lower the complexity of a D-OMA destination, which assigns the same order to each unit for all serving APs. Relating to all operating APs/BSs, the best order for D-OMA cluster members may be obtained.

Next-generation wireless networks, such as 5G and 6G, would incorporate various frequencies, requiring variable structures for transmission power and network architectures. The D-OMA parameters must therefore be built in the used frequency range, including the overlapping percentage δ. If δ is not correctly selected, this can have a very high ICI effect. Alternatively, lower frequency bands will suffer less spread loss. The transmission power requirements would also be lower. Consequently, the output of DOMA in lower frequency bands is possibly better than in higher frequency bands, at the highest δ values.

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TABLE III
GENERAL COMPARISONS OF 1G TO 6G

Generation	MAS	Application	Frequency	Core Design	Bandwidth	Advantage	Disadvantage
1G	FDMA	AMPS	30 KHZ	PSTN	2.4 Kbps	Secrecy and safety to data and voice calls	Limited capacity
2G	TDMA	GSA	1.8 Ghz	PSTN	64 Kbps	Enabled services such as SMS and MMS (Multimedia Message)	Digital signals could be weak if there is no network coverage in any specific area
3G	CDMA	UMTS	1.6 – 2 Ghz	Packet network	2 Mbps	3G Internet allows mobile phone to use as a GPS navigation device	The frequency of 3G transmission is different, that implies that at each base station, the cellular service provider must setup the correct configuration, which can be expensive
4G	OFDMA	LTE	2 – 8 Ghz	Internet	200 Mbps	4G networks have a lot more coverage than other networks, such as Wi-Fi, which enables users to rely on hotspots in each region user visits	Multiple antennas and transmitters are used for 4G mobile networks. Therefore, consumers can experience much lower battery life on their mobile devices while on this network.
5G	NOMA – RSMA	MIMO, mm Waves	3 – 30 Ghz	Internet	1Gbps	High resolution and bi-directional large bandwidth shaping	Security and privacy issues yet to be overcome
6G	D-OMA	B5G	95 Ghz	Internet	1 Tbps	Holographic connection (Holographic connectivity) which means smooth coverage anywhere using Augmented Reality (AR)/ Virtual Reality (VR)	Many of the old devices would not be competent to 6G, hence, all of them need to be replaced with new one — expensive deal

III. COMPARISON AND RESULTS

The simulation is conducted in MATLAB. The system consists of a transmission and reception system for NOMA and OFDMA through a wireless channel with the additive white Gaussian noise (AWGN). For NOMA, independent random data was generated for the upper layer (UL) and lower layer (LL). The original data is coded, considering the coding rates of the respective layers in each simulation. In the UL layer case, coding rates of 4/5 and 9/10 were used with a QPSK modulation, while in the LL layer, coding rates of 1/3 and 2/5 were used with 16-QAM modulation. An injection factor (g) was applied to the LL layer, which determines the power level of the LL with respect to UL, can vary between decimal values from 0 to 1. Next, the OFDMA symbol is formed to be transmitted on the AWGN channel and subsequently receive the signal as an OFDM symbol using the same coding and modulation parameters of the transmission stage. It must be taken into account that for the recovery of the information of each layer there is different complexity in the receiver, that is, to obtain the resulting information from each layer different processes are carried out. In the UL layer, the OFDMA receiver signal is used, and it is demodulated and decoded to obtain the layer information. The lower layer has noise in the process. In the LL, it is necessary that the OFDMA receiver signal is stored in a Buffer, using the information of the encoded and modulated UL to cancel the stored signal and obtain the corresponding information from the LL. For OFDMA a similar process is applied and analyzed using two simulations. The first case is implemented with parameters of the UL and the second case with parameters of the LL, to make the respective comparisons with the NOMA communication system and its respective layers, performing 1000 iterations to obtain the presented figures. TABLE III provides general comparisons of 1G to 6G networks in different terms.

The analysis of the figures was performed based on the behavior observed in each of the parameter combinations, BS identifies the i-th user's signal, it decodes the j-th ($j<i$) user's signal first and after that eliminates $(i-1)$ users' signals from y observation. Interference is the remaining $(K-i)$ signals.

A. NOMA vs OFDMA

Fig. 8 shows a comparison of NOMA and OFDMA structures. The technology of access to the medium that is currently in use for 5G is the multiple access variant of OFDM called OFDMA. For this reason, the figures generate a contrast between NOMA and OFDMA in order to observe the differentiation of non-orthogonal systems with orthogonal systems. We assume that $|h_1|^2/N_1 \geq |h_2|^2/N_2 \geq \cdots \geq |h_K|^2/N_K$, and a descending-order-based power allocation $p_1 \leq p_2 \leq \cdots \leq p_K$ can be taken into consideration. Assuming that the interfering signals are decoded fully error-free, the attainable user rate R_i (i = 1, 2,..., K) can be given as [97]

$$R_i = W \log_2 \left(1 + \frac{p_i |h_i|^2}{\left(\sum_{j=i}^{i-1} p_j \right) |h_i|^2 + N_i W} \right), \tag{7}$$

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where W is the bandwidth.

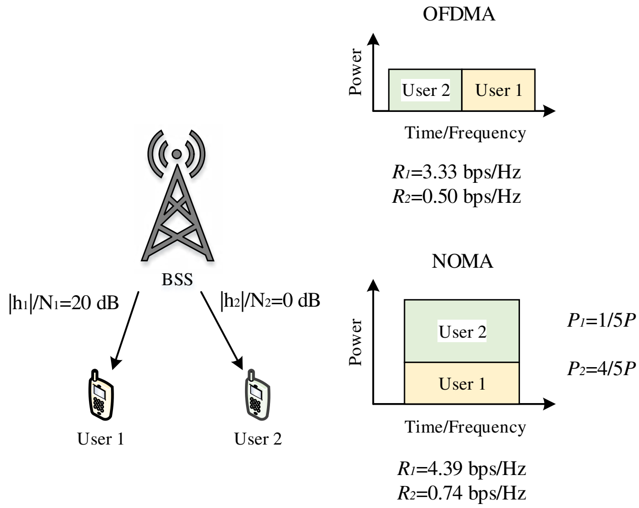

FIGURE 8. OFDMA vs NOMA

It should be noted that in the figure 8, since they are multiple access, resource is made to the use of the spectrum that users have. A better use of the NOMA spectrum can be observed. Since the two users with these multiple access schemes are assigned a better relationship bps / Hz, as long as it is in symmetrical environments. The parameters for the transmission of both users present similar characteristics. In this case, the curve shown by NOMA is more accurate in terms of resource allocation. Still, the great problem presented by NOMA is the implementation in non-symmetrical environments. NOMA vs. OFDMA comparisons is shown for bit rate per user and spectrum efficiency in Figs. 9 and 10, respectively. TABLE IV contains simulation parameter values for Figs. 9 and 10.

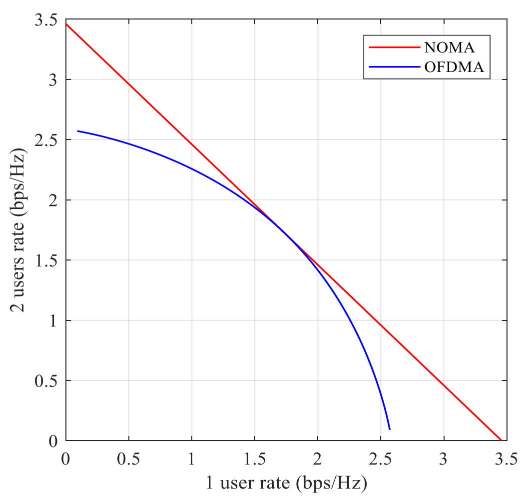

FIGURE 9. Bit rate per user (NOMA and OFDMA)

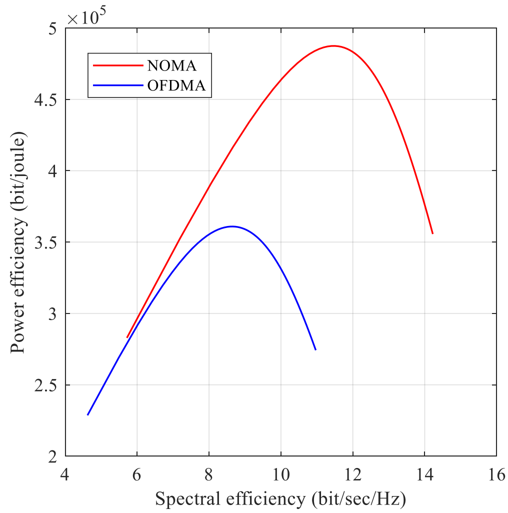

FIGURE 10. Spectrum efficiency comparison of NOMA and OFDMA

TABLE IV
SIMULATION PARAMETERS FOR FIGURES 7 AND 8

Gain for User 1	10
Gain for User 2	10
Max number of users	56
Max spectral efficiency measured in Bits/Hz	600
Count	2
Achievable rate of each user vs. normalized offset using NOMA with two users	K = 2

A comparison between spectral efficiency and energy efficiency is depicted. We can see how NOMA presents an apparent better behavior in spectral efficiency because it gives us more bits per Hz in terms of energy efficiency. Energy consumption increases for definite users. Due to the higher processing load, the information would undergo demodulation to be presented to the user. On the contrary, OFDMA is more efficient in terms of energy consumption. It does not exceed 4 bits/joule for the same scenario that NOMA occupies. Therefore, OFDMA makes better utilization of spectrum and energy resources to the transmission of information. TABLE V illustrates the advantages and disadvantages of OFDMA and NOMA.

TABLE V
COMPARING PROS AND CONS OF BOTH OFDMA AND NOMA

Method	Pros	Cons
OFDMA	No intracellular interference higher spectral efficiency and MIMO compatibility.	Needs synchronous multiplexing lost links for large number of users.
NOMA	It allows asynchronous multiplexing.	Not suitable for higher spectral efficiency. Requires further processing for receiver.

Supporting K users in the uplink of an AWGN channel (K can be greater than 2) [97]

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$$\sum_{i=1}^{K} R_k \le W \log\left(1+\frac{\sum_{i=1}^{K} p_i}{N_0 W}\right), \tag{8}$$

where N_0 represents the power spectral density of Gaussian noise. Comparison of channel capacity for OMA and NOMA is given in Fig. 11. More particularly, capacity of multiple access channel can be given as [98]

$$R_k = W \log_2\left(1+\frac{p_k |h_k|^2}{\left(\sum_{j=k+1}^{K} P_j\right)|h_k|^2 + N_0 W}\right). \tag{9}$$

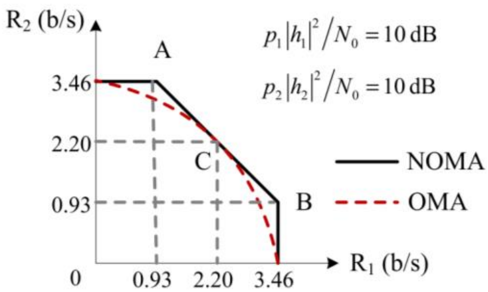

FIGURE 11. Comparison of channel capacity between OMA and NOMA.

B. D-OMA vs NOMA

In D-OMA, we permit diverse NOMA groups with neighboring recurrence groups to cover by a measure of δ% of their most extreme assigned sub-band (i.e., δ=0 compares to conventional power-domain NOMA). The size of each NOMA cluster can be reduced to adjust for the ICI introduced by overlapping NOMA clusters. The cumulative amount of the INI and ICI stays precisely equal to the magnitude of the INI when using non-overlapping large in-band NOMA clusters. Consequently, by incorporating more clusters within the same allotted total range, the spectral efficiency obtained by a sizeable in-band NOMA cluster is retained. At the same time, by diminishing sizes of various NOMA bunches, the degree of multifaceted nature prerequisites and force utilization of gadget SIC be essentially reduced.

In contrast, a similar presentation prerequisite is kept up as in the past. The level of covering among NOMA groups is viewed as a plan boundary in the worldwide streamlining issue that accomplishes ideal bunching for NOMA gadgets and their capacity distribution. Fig. 12 demonstrates a spectrum vs. power efficiency comparison of NOMA and D-OMA. Parameters are used in the D-OMA simulation of performance are presented in TABLE VI.

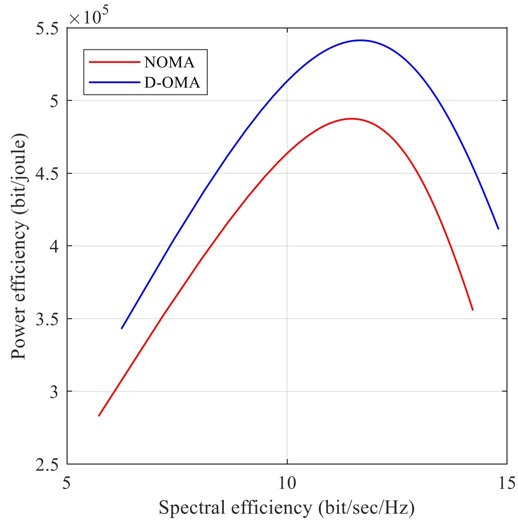

FIGURE 12. Spectrum vs Power efficiency comparison of NOMA and D-OMA

The downlink transmission rate at the gadget inside a certain NOMA group can be given as [3]:

$$R_i = W \log_2\left(1+\frac{\sum_{j=1}^{K} p_{i,j} |h_{i,j}|^2}{\sum_{j=1}^{K} \Lambda_j |h_{i,j}|^2 + \eta I_{\text{ICI}} + N_i}\right). \tag{10}$$

where $\Lambda_j = \sum_{j=1}^{M} p_{j,k}$. $h_{i,j}$ is the complex gain in the channel between the user of i-th NOMA and the AP serving K-th.". A smaller cluster size (M) would result in a lesser Λ_j and, thus, a higher signal-to-interference-plus-noise ratio (SINR) at i-th device for the same K. η denotes the percentage of NOMA clusters overlapping. We consider I_{ICI} is same as the 10% of maximum power budget per AP.

TABLE VI
PARAMETERS ARE USED IN THE D-OMA SIMULATION OF PERFORMANCE

Cell Layout	Hexagonal 19 cells
Distance between APs	0.3 km (simulated)
Transmission bandwidth	4.3 MHZ
Number of users M per cell	64
I_m	zero due to the comprehensive cooperation among APs and orthogonality among NOMA clusters
The value of β	relies on unified link quality metric used with regard to all serving APs in ordering the devices of a definite cluster.
The global ordering rank of the m[th] N_m and β	Derived from $\gamma_{m,k} = |h_{m,k}|$

C. NOMA vs SCMA

In addition to the new waveform proposals, possible new alternatives for multiple access methods are also being considered, such as SCMA, briefly described below.

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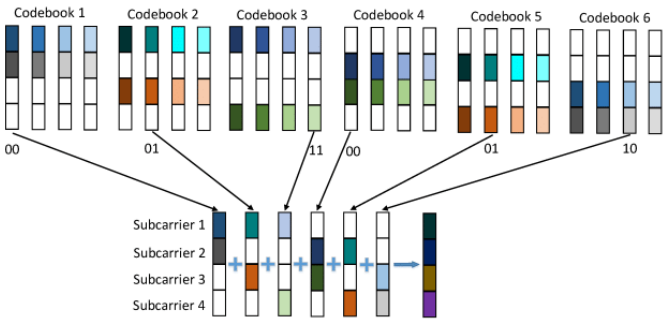

FIGURE 13. SCMA Codebook.

In this technology of multiple access with sparse codes, with the bits coming from the channel encoder of the transmitter, a joint expansion-modulation processing is carried out that transforms blocks of those bits into code words extracted from a repertoire codebook, whose elements are symbols of a multidimensional constellation. In Fig. 13, the block diagram is represented. As the SCMA signal looks at the output of the processor, a conventional OFDM modulator is carried.

Although similar in concept to that carried out in CDMA, the expansion differs from it in the constitution of the codes used. In CDMA, codes are "compact" or dense with all of their non-zero elements. (Values±1). In SCMA, however, codewords contain a large number of zeros. Furthermore, these sparse codes are contained, as has been said, in a repertoire of conveniently designed codes, each of which defines a layer (layer) and contains *K*=2m symbols, m is the number of bits of the incoming block to the module expander. Of these *K* symbols, *N* are non-zero and are taken from a multidimensional constellation. The choice of this type of constellation is because it offers greater possibilities of the minimum distance between the points of the constellation, which implies a reduction in the probability of error. Therefore, the iterative equation can be written as [97].

$$m_{n\to k}^{(t)}(x_k) \propto \sum_{\{x_i|i\in N(n)\backslash k\}} \frac{1}{\sqrt{2\pi\sigma}} e^{\left\{-\frac{1}{2\sigma^2}\left(y_n - h_{n,k}x_k - \sum_{\{i\in N(n)\backslash k\}} h_{n,i}x_i\right)^2\right\}} \times \prod_{\{i\in N(n)\backslash k\}} m_{i\to n}^{(t-1)}(x_i) \quad (11)$$

If *w* is the maximum users number superimposed at the identical chip, then the receiver complexity follows the order of O($|x_w|$) rather than O($|x_K|$) ($K>w$). TABLE VII contains specification for SCMA prototype.

Non-null elements occupy a unique and exclusive position on each layer called a sparsity pattern. The number *J* of layers is same as the number of combinations of *K* elements. The overload factor (overlaid factor) is the ratio J/*K* expressed as a percentage. As an example, Fig. 13 illustrates the principal diagram of an SCMA encoder with J=6 layers (6 repertoires), for input bit blocks of size *m*=3. The size of each word, that is, the length of the expansion is *K*=4 and number of non-zero elements is N=2, so 6 layers can be formed. Each 3-bit input block is mapped to a code word. The example in the figure shows, in different colors, the code words assigned by the layers to the blocks: 011 of user 1 (layer 1), 000 of user 2, and so on until block 111 of user 6.

TABLE VII
SPECIFICATION FOR SCMA PROTOTYPE

Mode	Values
Number of active UEs	12 out of 14
Transmit power of UE	23 dBm (max) with open-loop power control
Basic waveform	OFDM/F-OFDM
MIMO mode	1 by 2 SIMO
Center frequency/bandwidth	2.6 GHz/20 MHz
Scheculed resource	48 RBs/4 RBs
Code rate	0.3-0.92
SCMA codebook	24 by 8, 4 points
Frame structure	TDD configuration 1, 4 subframes for PUSCH

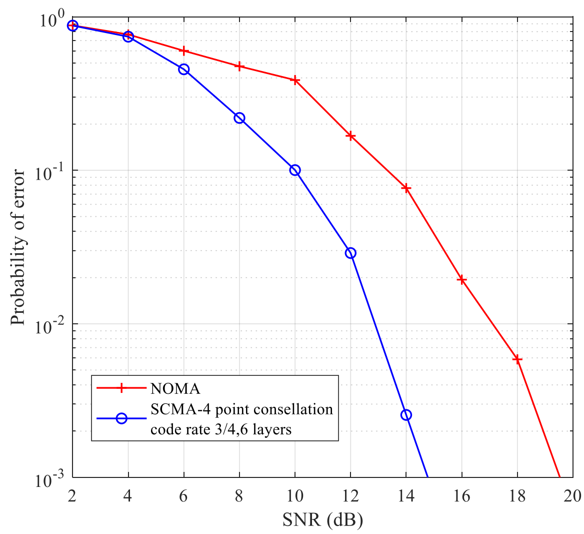

FIGURE 14. Probability of error in NOMA and SCMA with Huawei Specification.

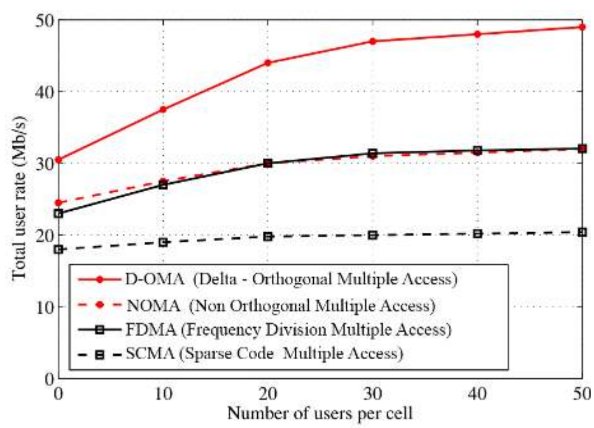

FIGURE 15. The comparison of spectral efficiency of the SCMA, FDMA, NOMA, and D-OMA.

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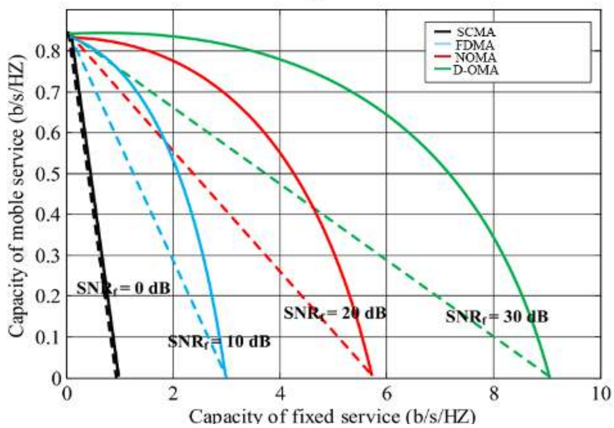

FIGURE 16. **A collective figure showing the capacity of SCMA, FDMA, NOMA, D-OMA.**

Fig. 14 shows the probability of error in NOMA and SCMA with Huawei specification. A collective figure of the SCMA, FDMA, NOMA, D-OMA spectral efficiency and capacity per number of users are presented in Figs. 15 and 16, respectively.

The bar obstruction can be smothered by spatial sifting, which is like the sign recognition calculation of inadequate code for SCMA. A couple of impedance dropping approaches are utilized for eliminating the between pillar impedance and the intra-pillar impedance. Expecting that the spatial separating vector of the i-th client in the b-th pillar is $\mathrm{f}_{b,i}$ the sign $\mathrm{z}_{b,i}$ after spatial separating can be written as [97].

$$z_{b,i} = \mathrm{f}_{b,i}^{H}\,\mathrm{y}_{b,i} = \mathrm{f}_{b,i}^{H}\,\mathrm{H}_{b,i}\,\mathrm{m}_{b}\sum_{j=1}^{k_b}\sqrt{p_{b,j}}\,x_{b,j} + \mathrm{f}_{b,i}^{H}\,\mathrm{H}_{b,i}\sum_{\substack{b'=1\\ b'\neq b}}^{B}\sqrt{p_{b',j}}\,x_{b',j} + \mathrm{f}_{b,i}^{H}\,\mathrm{v}_{b,i} \quad (12)$$

where $\mathrm{H}_{b,i}$ represents the channel matrix of size.

In the uplink systems, the capacity of these methods related to K users, where BS is hardwired with several antennas and there is a single transmitter antenna for each user, the signal obtained at BS can be given as:

$$\mathrm{y} = \sum_{i=1}^{K}\mathrm{h}_i\sqrt{p_i}\,x_i + \mathrm{v}. \quad (13)$$

where x_i are the transmit power. v linked with the power density N_0 denotes Gaussian noise and inter-cell interference at BS.

The size of each word, that is, the length of the expansion. Although a similar concept is carried out in CDMA, it differs from it in the constitution of the codes used in SCMA. However, code words contain many zeros. Therefore, we speak of low-density and sparse spreading codes. Furthermore, of these K symbols, N is non-zero and are taken from a multidimensional constellation. TABLE VIII compared the power domain-based expansion vs. the code domain-based expansion:

TABLE VIII
POWER DOMAIN BASED EXPANSION VS THE CODE DOMAIN BASED EXPANSION

Schemes	**Power Domain Based**	**Code Domain Based**					**Interlayer Based**
	SPC-NOMA	**MUSA**	**SCMA**	**PDMA**	**RSMA**	**NCMA**	**IGMA**
Scenario	DL-eMBB	UL: mMTC, URLLC DL: eMBB	UL: mMTC, URLLC DL: eMBB	UL: mMTC, URLLC DL: eMBB	UL: mMTC, URLLC	UL: eMBB mMTC, URLLC	UL: eMBB mMTC, URLLC
Multiplexing Domain	Power	Code/ Power	Code/ Power	Code/ Power/ Spectral	Code/ Power	Code	Interleaver
Transmitting Overhead	Low/ Medium	High	Medium /High	Medium/ High	Low	High	High

As a final summary, TABLE IX summarizes the performance of the different methods with respect to the most relevant characteristics.

TABLE IX
PERFORMANCE OF THE DIFFERENT METHODS WITH RESPECT TO THE MOST RELEVANT CHARACTERISTICS

PARAMETER	**SCMA**	**RSMA**	**NOMA**
Spectral Efficiency	Medium	High	High
Processing Complexity	Medium	Medium	High
ISI / Multipath Distortion	Low	Medium	Low
Latency	Short	Medium	Short
Compatible with OFDM	Yes	Yes	No

VII. CONCLUSION

With the rapid growth of cellular technology, various investigations are being carried out to continue ensuring the sustainability of mobile communication services. Users are increasingly demanding a higher quality of service, higher speeds, and better connectivity among others. This paper's general objective is to evaluate the simulation-level performance of multi access techniques such as OMA, NOMA, and the newly developed D-OMA for 6G. For this, it is necessary to study the traditional techniques of access mechanism that have existed in the history of mobile communications that is OMA. The operation and the advantages and disadvantages of each OMA technique (FDMA, TDMA, CDMA, and OFDMA) are defined in each of these techniques. Moreover, NOMA and D-OMA are studied in detail. The benefits and difficulties that this scheme can generate in next-generation cellular telephony are mentioned. An evaluation and comparison of the transmission rate at the cell level between NOMA and OMA and the new D-OMA method are presented. The NOMA technique is superior to OMA as long as the power allocation is correct, yet not as much as D-OMA, achieving higher spectral efficiency when enough clusters are supplied.

Many researchers have been working on NOMA techniques and their implementation and the solution of different technical problems. The literature shows that NOMA is companionable with cooperative communications, relay, and MIMO and improves performance ominously. Researchers introduced techniques that easily enhance the low data rate and low quality of cellular networks through NOMA coordination. In addition to the literature's study questions, there are many other problems and open issues which must be addressed. One of the challenges is the allocation of resources. In comparison, NOMA has been taken to scientists' attention by developing resource allocation algorithms to NOMA as a possible radio access technology in next-generation communication systems due to different practical challenges. These include scalability, the existence of multi-cell interference, integration of carrier aggregation, allocation of resources under minimal channel input, QoS-assured allocation of resources, and intercell communications.

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