



A Survey on Advanced Multiple Access Techniques for 5G and Beyond Wireless Communications

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Accepted: 14 January 2021 / Published online: 31 January 2021

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Abstract

This paper summarizes the ongoing research initiatives based on the advanced multiple access techniques towards the fifth generation (5G) wireless communication and beyond. Prior cellular network generations have embraced various multiple access techniques with a common feature that is to have orthogonal signals at the side of the receiver for different users. The diverse requirements of huge number of connections about latency and throughput is the need of the hour. Therefore, 5G wireless systems and beyond, are preferring the design method to shift towards non-orthogonal from orthogonal in multiple access techniques. The paper will mainly focus on the non-orthogonal multiple access techniques considering the types of its candidates in multiple domains which can help us in identifying the impacts on the designs of multiple access for 5G network and beyond. This survey aims to discover the obstacles and possibilities of utmost importance for multiple access designs for 5G networks.

Keywords Multiple access techniques · 5G · 5G and beyond · NOMA

1 Introduction

Cellular communication technologies have evolved from second generation (2G) Global system for mobile communication (GSM) to fourth generation (4G) Long term evolution—Advanced (LTE-A) during the last two decades. An array of multiple access techniques (MA) is used by the cellular standards including frequency division multiple access (FDMA), Time division multiple access (TDMA), Code division multiple access (CDMA), and orthogonal-frequency division multiple access (OFDMA) which are a form of orthogonal multiple access (OMA) [1]. Here, theoretically, there is no interference with one another while sharing the wireless medium except in CDMA, where non-orthogonal transmission takes place from wireless device to base station. In OFDMA, at various time

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slots, clients are assigned to the different categories of sub carriers. OFDMA is still utilized for the next-generation cellular systems where the duration of the time slot and the sub-carrier spacing is flexible for supporting wide varieties of use cases and needs.

Therefore, 5G advancement and 6th generation (6G) innovation is expected to be a prominent candidate for bolstering industry and society in the 2030s. The third generation partnership project (3GPP) suggests four key applications that need to be backed by 5G networks. They comprise massive machine type communications (mMTC), enhanced mobile broadband (eMBB), ultra-reliable and low-latency communications (URLLC), and the enhanced vehicle-to-everything (eV2X) communications. 5G needs to fulfill the new requirements of all these applications such as improved spectral efficiency (SE) and high system throughput catering to massive connectivity by exploring new modulations and multiple access schemes. 4G and current broadband transmission have adopted orthogonal frequency division multiplexing (OFDM) method wherewith simple detection scheme and appropriate cyclic prefix, it can avoid the wireless channel's delay spread. However, the broad requirements of the 5G networks are not satisfied by the OFDM system.

The notion of multicarrier modulation (MCM) has appeared in [2] which explained the practical implementation using the Fast Fourier transform method. Access to frequency selective channels is allowed by MCM which uses high gain links and at the same time avoids fading dips. 4G LTE has been using OFDM in the downlink (DL) due to the benefits of the MCM techniques [3]. OMA is fundamental to all the wireless networks in which resource blocks (RB) are orthogonally divided in to three domains such as time, frequency, and code. Hence, signal detection becomes easy since there is minimal interference among adjacent blocks. However, a reduced number of users can be supported by OMA on account of restrictions in the total number of orthogonal RB, which restricts spectral efficiency and network capacity. By the provision of a huge number of and various categories of applications and their users within 5G networks, multiple nonorthogonal multiple access (NOMA) techniques have been proposed. Same resource elements are shared by multiple users in the NOMA technique. While CDMA has been considered as an OMA technique by a majority of recent works [4, 5]. With the expansion of Internet-empowered smart devices, its creative implementations are enabled by complex new services facilitated by the advancement of 5G systems that require new MA strategies. NOMA is classified into the following classes, (1) code-domain NOMA (2) power domain NOMA [6–9]. Power domain NOMA makes sure that several clients are given services inside a given RB. At the transmitter side, this is assisted by superposition coding (SC) and on the receiver side by successive interference cancellation (SIC), which is on a considerably basic level unique with the great OMA methods. NOMA is equipped for exploiting the accessible assets more productively by deftly benefiting from the client's particular channel situations and it is fit for serving various clients at various QoS prerequisites in a similar RB. OMA modulation techniques are classified based on pulse shaping, subband filtering, and other modulation techniques [10–13]. Major emphasis is on the classification of NOMA in this paper. The most prominent agent code-domain NOMA strategies [14, 15] incorporate, Interleave division MA (IDMA), and low-density spreading CDMA (LDS-CDMA) and LDS-OFDM. These arrangements are supplemented by the more as of late proposed multiuser shared access (MUSA) system, pattern division MA (PDMA) and sparse code multiple access (SCMA), the building block sparse constellation based OMA (BOMA), and Lattice partition multiple access (LPMA) as shown in Fig. 1.

The remaining paper is as follows. Section 2 describes what leads to NOMA as a 5G wireless candidate. Section 3 explains about the concept of NOMA followed by Sect. 6 which gives the detail about the categories of NOMA. Section 5 explains the superiority

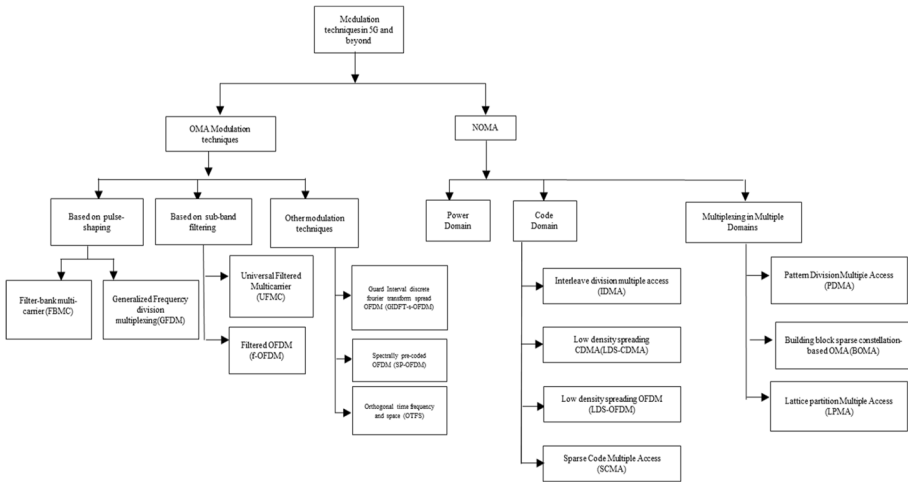


Fig. 1 Modulation techniques in 5G communication and beyond

of NOMA over OMA. Opportunities and challenges faced by NOMA are discussed in Sect. 6. Section 7 comprises some simulation results which explain the basics and few parameters associated with NOMA followed by the conclusion in Sect. 8 and future work in Sect. 9.

2 What Leads to NOMA?

Requirements of 5G communication and the network includes a peak data rate minimum of 10 Gbps (100 times greater than 3GPP-LTE), a latency of 1 ms (10 times smaller than 4G networks), and a connection density of 1,000,000 devices that are per km (100 times greater than 4G networks) [16]. NOMA can address all these challenges more efficiently and in a better way than the traditional OFDM scheme by letting many users to share all domains, time, frequency, and space, in the next generation of the wireless network. The main features of NOMA can be summarized as:

1. RB (time/code/frequency) can be exploited by multiple users which exhibits the fact of high spectral efficiency in NOMA [17, 18].
2. At the base station, perfect uplink channel state information is not needed in the case of NOMA. In the channel feedback, only received signal strength (RSS) information has to be incorporated.
3. NOMA supports greater connectivity for a large number of smart devices and can support multiple users within one RB which is one of the most important features of the internet of things (IoT) devices that require a multiple users with low data rates.
4. It is not needed to schedule requests from users to the base stations in the uplink-NOMA which is a requirement in case of OMA. Therefore, transmission latency reduces in NOMA and a grant free uplink transmission can be recognized.

3 Concept of NOMA

In a NOMA cluster, the superposition of different message signals of the different users is allowed [19]. When the user will be in the downlink and the base station in the uplink, the detection, and decoding of the desired message signal is done by applying signal interference cancellation at the receiver side.

3.1 NOMA Downlink Transmission

In the transmitter section of the downlink NOMA, the base station transfers the joined signal. That is the superposition of ideal waves of numerous clients with numerous distributed power coefficients, to every single mobile user. In the receiver section of every client, the successive interference cancellation on the system is believed to be implemented continuously till the customer’s signal is regained. Power coefficients of customers are allotted by the conditions of the channel, in an oppositely related approach. The customer has an awful channel condition is administered greater transmission power compared to one that has a better than average channel condition [20]. Therefore, the client with the most raised transmission power thinks about the signal of various clients as clatter, it recovers its signal expeditiously instead of implementing the SIC strategy. In any case, various clients need to perform SIC forms. In SIC, all the signals that are more grounded than an individual client’s grounded optimal signal are recognized by their receiver. Then, these signals are deducted from the acquired signal as shown in Fig. 2 where s: transmitter. This strategy is continued till the related customer’s inherent signal is settled or decided [21–23]. Lastly, every client disentangles their inherent signals by treating various clients with neither power coefficients as obstruction or commotion. The transmitted signal at the base station can be formed as given below:

$$S = \sum_{z=1}^L \sqrt{b_z P_S} x_z \tag{1}$$

where x_z is the client z (U_z) information with unit energy. P_S is the transmission power at the base station and b_z is the power coefficient allocated for client z subjected to $\sum_{z=1}^L b_z = 1$ and $b_1 \geq b_2 \geq \dots \geq b_L$ since with no loss of channel gains are believed to be ordered as $|h_1|^2 \leq |h_2|^2 \leq \dots \leq |h_L|^2$ where h_l is the channel coefficient of the l th client depending upon NOMA. The received signal at l th client can be expressed as:

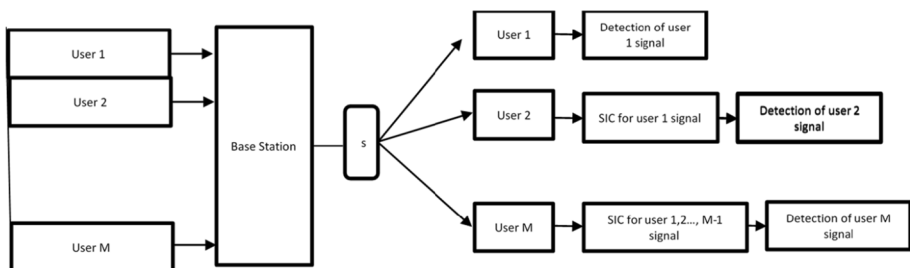


Fig. 2 Downlink NOMA transmission

$$Y_l = h_l S + n_l \tag{2}$$

where n_l is zero mean complex additive Gaussian noise with the variance of σ^2 .

3.2 NOMA Uplink Transmission

In the uplink, individual signals are transmitted by each of the users with a transmit power. Power transmitted per user is restricted to the user’s highest possible battery power. While the channel gains of the users are different, users can individually use the battery power to its maximum [24–27]. In this network, the signal is transmitted to the base station by the mobile user as shown in Fig. 3 where r: receiver. At the BS, SIC cycles are done to identify the signals of clients. By accepting that the downlink, as well as the uplink channels, are complementary to each other and the base station imparts power allocation coefficients to mobile clients, the wave which has been received at the base station for synchronic uplink-NOMA can be written as:

$$a = \sum_{z=1}^L h_z \sqrt{b_z P} x_z + n \tag{3}$$

where h_z : coefficient of channel of the z th user, P : max transmission power that is supposed to be identical for all the clients, N : zero mean complex additive Gaussian noise with variance of σ^2 .

4 Categories of NOMA

NOMA can be categorized into power, code and multiplexing of NOMA in multiple domains.

1. *Power domain NOMA*: It is a favorable multiple access technique for 5G networks [28]. It has been demonstrated that NOMA can improve the capacity of system and user experiences. This was proved when MUST was proposed. It is in particular a downlink form of NOMA for 3GPP LTE-A. Power-domain (PD) NOMA helps in distinguishing the multiple users with varying power levels inside the same time/frequency/code RB. PD-NOMA only has a single observation as opposed to CDMA or MIMO systems

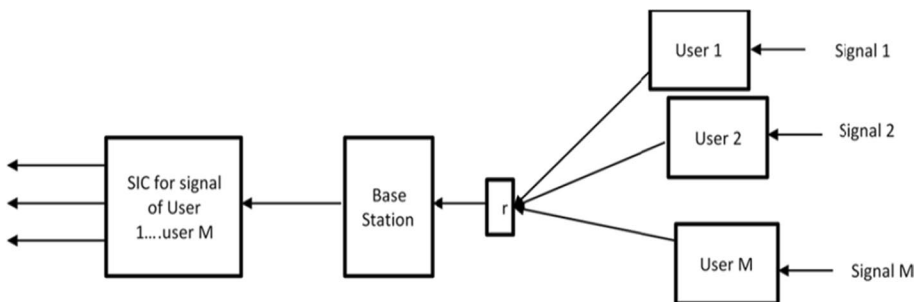


Fig. 3 Uplink NOMA transmission

which have multiuser detection [29]. The received signal at the base station in the uplink transmission of NOMA can be expressed as:

$$y = \sum_{b=1}^B h_b \sqrt{T_b} x_b + n \quad (4)$$

where T_b = Transmit power from the b th user, x_b = Transmit symbol from the b th user, n = AWGN with variance σ^2 , B = users number sharing the same RB.

The received signal-to-interference-noise ratio (SINR) of the b th NOMA user can be calculated for all correct first detected symbols as:

$$SINR_b = \frac{T_b |h_b|^2}{\sum_{a=b+1}^B T_a |h_a|^2 + \sigma^2} \quad (5)$$

2. *Code domain NOMA*: This scheme allocates multiple transmissions in similar time/frequency RB by assigning dissimilar codes to diverse users. In contrast with power-domain NOMA, it has particular spreading and shaping gain with the price of additional signal bandwidth. Current explanations to code-domain NOMA which have been discussed here are LDS-CDMA, LDS-OFDM, SCMA, and IDMA.
3. *NOMA Multiplexing in Multiple domains*: In multiple domains, solutions to the NOMA have been anticipated to multiplex, for example power, the code, and spatial domain, to provision massive connectivity for 5G systems. Other forms are PDMA, BOMA, and LPMA.

NOMA can be executed in different structures, for example, CD (code domain) and PD (power domain) NOMA. We may arrange the useful types of NOMA likewise into i) single carrier ii) multiple carrier NOMA. The points of interest and inconveniences for these will be inspected.

4.1 Single Carrier NOMA (SC-NOMA)

We start our analysis with single-carrier NOMA to build systems for numerous carrier's NOMA structures.

- *IDMA*: Major thought of the IDMA depends on a remarkable user/client explicit chip inter-leaver for recognizing the signals of various users. In this way, like chip-interleaved CDMA, IDMA provides an advantage of greatly assorted diversity gain [30]. In such a case, a few chips get debased; then low-complexity chip-by-chip iterative multi-user detection (IMD) methodology is used to recover the relating spreading sequence.
- *LDS-CDMA*: LDPC (low-density parity check) code can be examined to establish an improved variant of CDMA. For traditional CDMA, a promising arrangement for every client is to allocate orthogonal spreading sequences respectively, and henceforth to wipe out obstruction lower-complexity receiver are assembled at receivers. The main feature of LDS-CDMA is that it is mainly working for the codebook construction [31]. It is similar to in LDPC matrix. Regardless, this orthogonal spreading code configuration is just fit for supporting an equivalent amount of chips and users, which inspires the improvement of the non-orthogonal spreading code plan. Instead of dense spreading sequences of customary CDMA, alleged sparse spreading sequences are utilized

as in OVSF (orthogonal variable spreading factor) codes [32]. Such structure requires refined multiuser deciphering at the side of the receiver. At the receiver, a message-passing algorithm (MPA) taking into account multiuser-detection, can be implemented for LDS-CDMA, which is equipped for accomplishing the nearest ML (maximum likelihood) detection.

- *LPMA*: Lattice partition MA is a downlink non-orthogonal, multi-client superposition transportation scheme. It attains a multiplexing gain in power and code domain. By super imposing the different power streams, power-domain multiplexing expands its throughput [33, 34]. Conversely, code-domain multiplexing overlaps a few streams by taking advantage of the consolidation of lattice codes likewise brings about a lattice code. All added explicitly, LPMA ciphers the data of the client by the application of lattice coding on the transmitting end and conjures SIC on the receiving end for revelation. LPMA has the merit that it has the capability of bypassing hindrance of PD-NOMA, to be specific the performance gain relies upon the difference of channel characteristics of the clients. Be that as it may, LPMA forces a greater encoding and decoding complexity compared to the PD NOMA.

4.2 Multiple-carrier (MC) NOMA (MC-NOMA)

According to preferences given to OFDM waveform, this configuration is probably going to be joined in 5G systems. Primary advantages of MCM are that rather than the short dispersal basically for subtle symbols of sequential modems, several of the parallel long-term spreading safe symbols get transported across the dispersive channels. Henceforth, these long-span symbols can be smoothed out through a single tap frequency domain equalizer. In these segments, a few types of MC-NOMA plans are worked upon.

- *LDS-OFDM*: It is a blend of LDS-CDMA [35] as well as OFDM, and it can be viewed as a propelled variation of LDS CDMA in a diversified-carrier system. Consequently, the transmitters use equivalent sparse spreading sequences and the equivalent MPA-dependent recognition is embraced at the receiver side. The information stream mapping procedure comprises of dual stages: (1) every bit of information stream is foremost disseminated by the LDS sequences, and (2) information streams are transported upon various subcarriers by employing OFDM-modulator. Various strategies for mapping of spreading sequences on OFDM are present, and all of them have various advantages as well as disadvantages. For instance, each chip might be profiled to an alternate subcarrier for accomplishing the diversity of the frequency domain. Then again, each subcarrier may pass on a spread lower-rated stream. Be that as it may, this structure brings about a higher multifaceted nature because of the utilization of MPA recognition contrasted with an ordinary OFDMA scheme.
- *SCMA*: The sparse codebook is like low density spread based signature matrix. Through spreading, a certain number of RB can provision more users. Figure 4 shows the SCMA encoder where six users contribute to four RB. SCMA increases the overall connectivity and rate as it supports the overloaded access over the coding domain [36–39]. The coding, as well as the shaping gain, can be achieved at the same time by creating the codebook and multi-dimensional modulation constellations. Even though the same block is shared by the users, another block would be accepted to differentiate several users during the occurrence of collisions.

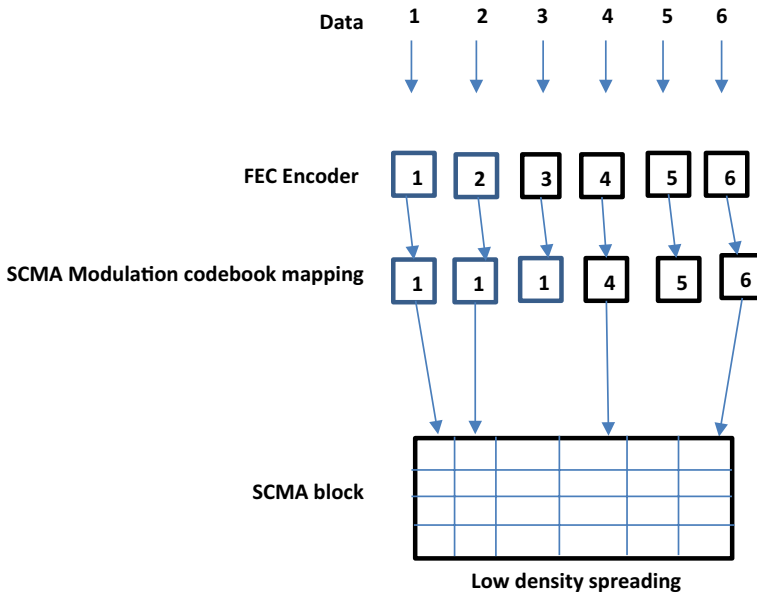


Fig. 4 Sparse code multiple access encoding

- PDMA:** It is a different type of sparse signature matrix-based multiple carriers NOMA. PDMA permits changeable numerous clients to be plotted to every RB. For instance, the main client supposedly activates all the subcarriers for transmission, while the 6th client just initiates a solitary subcarrier [40]. Another principle contrast among PDMA as well as SCMA is PDMA does not aim for accomplishing a constellation shaping gain, that gainfully maintains a strategic distance from the complicated multi-spatial constellation pattern plan of SCMA. On the receiver side, the MPA might likewise be embraced for combined deciphering, which is like LDS-CDMA as well as SCMA. Besides, additional MPA SIC location methodologies can likewise be utilized for improving the decoding performance.
- BOMA:** Building blocks sparse constellation-based OMA is a method that attributes the information from a user with decent channel state information to the symbols of a user with inadequate channel state information. This scheme enhances the capacity of the multiuser system. The configuration of BOMA is simple and easy and has been accepted in the present 4G systems. To implement BOMA with high-frequency bands and massive MIMO, some modifications to the software are essential. Changes should be such that it is compatible with the other 5G requirements as well. Moreover, BOMA requires no complicated power allocation and successive interference cancellation receivers that are required for other NOMA schemes.

5 Superiority of NOMA over OMA

- Considering spectral efficiency as well as throughput, in OFDMA a particular frequency asset is allotted to every client even if it encounters a great or awful channel state; in this way the general framework experiences lower spectral efficiency and also

lower throughput. In NOMA, almost similar frequency asset is allocated to various mobile clients, with great and awful channel situations, simultaneously. Consequently, the resources relegated for the fragile client are likewise brought into use by the powerful client, and the obstruction can be alleviated by SIC at the user's receiver side. Along these lines, the chances of having large throughput and spectral efficiency will be substantially expanded.

- Considering massive connections, lower latency, and user fairness, in OMA, such as in OFDMA with organizing client by a reasonable channel situation has a considerable requirement to be carried out, although client with an awful channel scenario needs to hang tight, which prompts a fairness issue and higher latency. This methodology cannot bolster a massive network. Notwithstanding, NOMA can serve numerous clients with different channel situations at the same time; consequently, it can give a better user fairness, low latency, and heavy massive connections.
- In the case of being accordant, NOMA is likewise perfect with the present and eventual communication frameworks after all it does not feel a necessity for huge adjustments on the actual composition.

6 NOMA: Opportunities and Challenges

A definite objective of utilizing NOMA is to accomplish greater spectral efficiency along with sensible user fairness. It is presented as a worldview change because of the plan of future radio access strategies. NOMA is good with different propelled communication strategies and schemes to be utilized in the fifth generation and beyond it. Nonetheless, the open doors accompany different opportunities and challenges [41–46]. Few of them are as laid out underneath:

6.1 NOMA Based Heterogenous Network

With regards to 5G prerequisites, a heterogeneous network (HetNet) is a compelling answer to accomplishing high capacity upgrades, brilliant usage of limited assets, and minimal cost networks. In HetNets, notwithstanding essential BS also known as macro-BS, there are different kinds of mini BSs, for example, micro and pico-BS in every cell, rather than a homologous network that has just a single BS in every cell [47–49]. The mini BSs with lesser transmit powers and littler coverage are introduced inside the inclusion of the macro cell to increment spectral-efficiency and quantity of offered clients. NOMA-based HetNet essentially boosts the downlink coverage in collaborative-communication. The NOMA-dependent two-level HetNet with non-uniform mini cell formation is discovered higher energy proficient contrasted with OMA-empowered HetNet. In NOMA-based multi-cell systems, the control of power is a fundamental affair to concentrate on the grounds that both intra-cell intervention and inter-cell noise should be coordinated.

6.2 NOMA in mmWave Communication

MmWave correspondence speaks to specifically the most encouraging innovations for the 5th generation and beyond due to its enormous bandwidth assets. Its applications are feasible in a different context, for example, IoT and cloud-helped vehicular networks. Be that as it may, the presentation of mmWave frameworks [50–54] is seriously degraded on

the grounds that its transmission is exceptionally directional, and along these lines, user's channels are profoundly correlated. Interestingly, such an excessive interconnection is a great prerequisite for the utilization of NOMA. The utilization of NOMA in millimeter-wave has been examined in various locales and situations, and NOMA is demonstrated to be much more effective than OMA. Regardless of its potentiality, investigation of mmWave which is NOMA-based communication is yet in the beginning time. Consequently, multidimensional analysis, for example, resource allocation improvement, cooperative millimeter Wave NOMA, and mmWave NOMA HetNets are needed to additionally support the framework execution.

6.3 Visible Light Communication (VLC) Based NOMA

Despite the mmWave communications, an additional communication worldview with good spectrum resources that have pulled in huge consideration as of late is VLC. By reason of light can't infiltrate by walls, VLC inalienably proposed a more significant height of data security [55–58]. In addition, VLC is especially helpful in some delicate conditions, for example, airplane cabins as well as clinics, where the obstruction to actual radio frequency (RF) frameworks is commonly risky. In spite of the significant contrasts amid VLC as well as RF channel, the utilization of NOMA to the downlink VLC situation can possibly additionally expand the exhibition of VLC systems without influencing the light-emitting diode lighting character. Further research should be done to make NOMA-empowered VLC useful in various environments and situations remembering NOMA for uplink VLC as well as MIMO NOMA in VLC. An open issue is additional which is of resource allocation in NOMA-aided VLC.

7 Results and Discussion

1. *NOMA at Transmitter:* The transmission and reception are done simultaneously by the two under the NOMA scheme using the same frequency. Figure 5 shows that at the transmitter side, superposition coding is done. Two users x_1 and x_2 are assumed to be communicating simultaneously using the same frequency having 4 bits of data each sends where $x_1 = 1111$ and $x_2 = 1110$. BPSK has been considered which maps 0's to -1 's and 1's to $+1$'s. $\times 1$ and $\times 2$ has been multiplied with different power levels and then added together. They both have unit power as the peak amplitude of $+1$ and -1 has been observed. Power weights a_1 and a_2 has been considered as 0.5 each considering the rule of summing up to 1. Considered the fixed power allocation, values of a_1 and a_2 are fixed. Since a_1 and a_2 depicts the power scaling factors so, scaling has been done for scale x_1 and x_2 with $\sqrt{a_1}$ and $\sqrt{a_2}$, respectively.
Amplitude scaled versions of the data are, $\sqrt{a_1}x_1$ and $\sqrt{a_2}x_2$. Scaled output has been added to get the superposition coded signal output which is denoted by $x = \sqrt{a_1}x_1 + \sqrt{a_2}x_2$.
2. *NOMA at receiver:* Successive Interference Cancellation (SIC) is an operation performed on the receiver end that makes NOMA possible where data is decoded in the order of decreasing power levels. BPSK demodulation has been directly applied to x and the threshold has been set to zero. If the amplitude exceeds zero, we are going to decode it as 1, and 0 otherwise. Three main steps of performing SIC are to get the signal which has been weighed with high power, multiplying the signal which has been decoded by

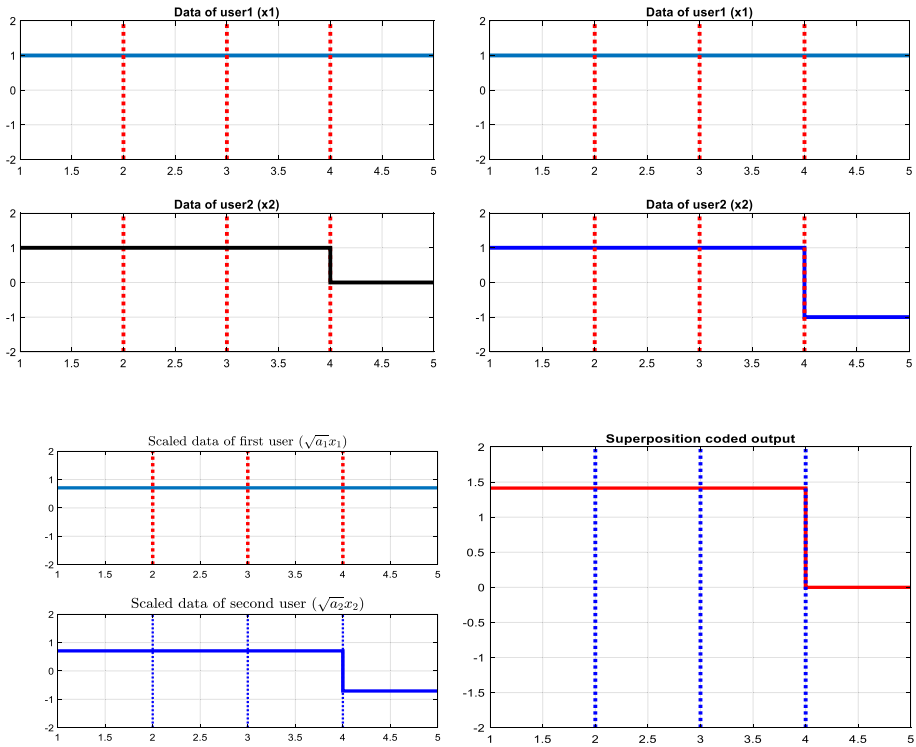


Fig. 5 NOMA at the transmitter side

its corresponding weight and subtract it from x , and finally to decode the signal which has been obtained so as to get the other signal which was multiplexed with low power as shown in Fig. 6.

3. *NOMA-BER in AWGN channel*: Two user NOMA system using MATLAB is simulated and the performance of BER versus SNR is plotted in the AWGN channel. To estimate the BER, the comparison is made in decoded and transmitted bits by using the inbuilt biterr() function. A waterfall trend is observed in which user 2 has lower BER than user 1 in the low SNR region. The data must be decoded correctly by user 2 for both user 1 and its own since user 2 must do SIC. If any error occurs during the decoding, it will have an impact on BER directly. This is the reason why user 2 has a high value of BER than user 1 as shown in Fig. 7.
4. *NOMA: Outage probability and capacity for Rayleigh fading channel* Non-line of sight (NLOS) path use Rayleigh fading model in between the transmitter and the receiver. Due to multipath transmission, each bit that has been transmitted goes under a different phase shift and attenuation. The capacity and outage power of NOMA has been plotted here concerning transmitting power. It has been observed that the SNR and achievable rates have been calculated with their average and outage has been checked upon considering the distance of the users from the base stations as 500 and 1000 m and power allocation factors as 0.7 and 0.3 where R_1 , R_{12} , and R_2 are average achievable rates as observed in Fig. 8.

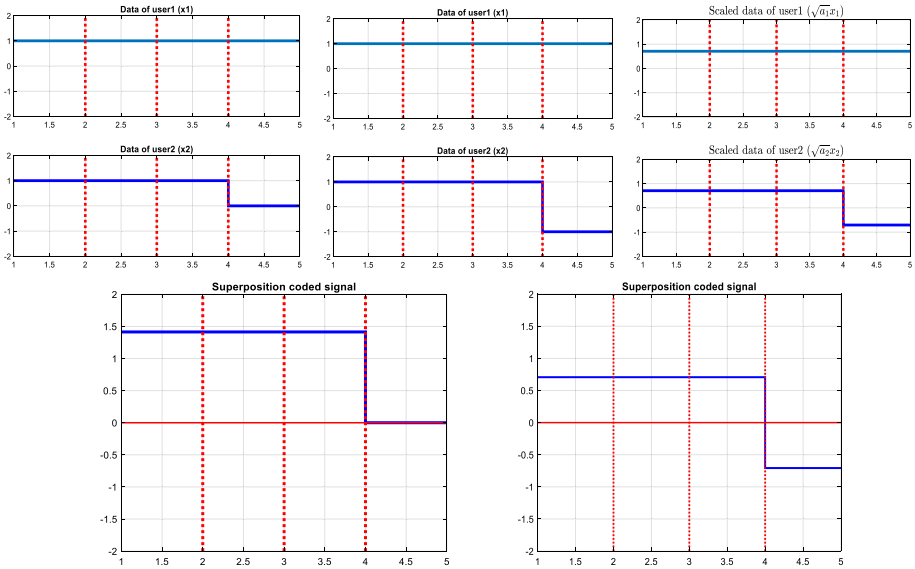


Fig. 6 Successive Interference Cancellation steps for NOMA

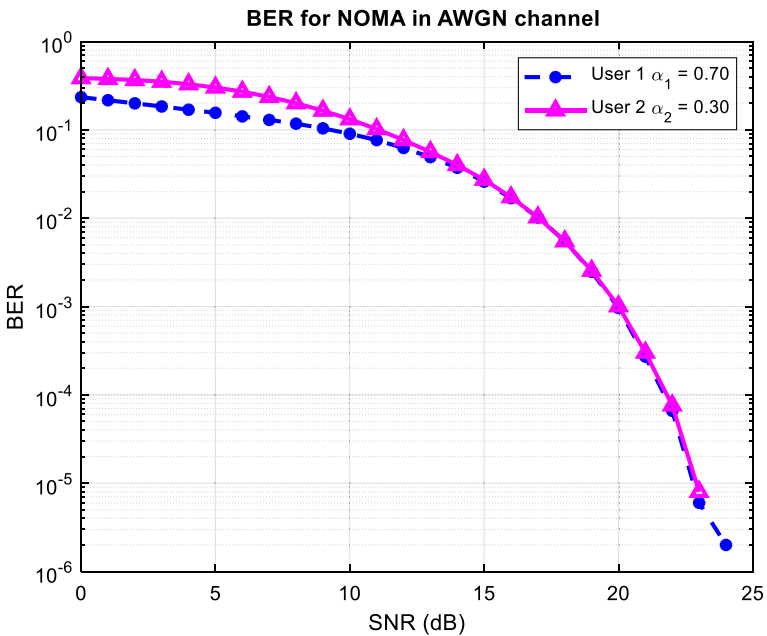


Fig. 7 NOMA-BER for AWGN channel

5. *NOMA-BER for Rayleigh channel:* Once the outage and capacity have been plotted, noise samples have been generated for both the users followed by the random binary data. BPSK has been used for modulating the data and superposition coded signal x has

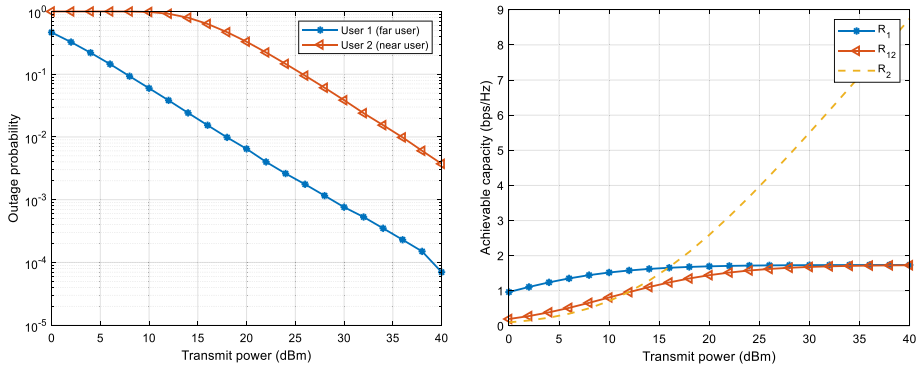


Fig. 8 NOMA-outage probability and capacity for Rayleigh channel

been calculated followed by the received signal y_1 and y_2 . BPSK demodulation has been performed once the output signal is equalized. As shown in Fig. 9 BER as a function of transmit power has been plotted while not considering the dBm value and only using the linear value of power in all the analysis, also theoretical BER has been referred to.

6. *NOMA versus OMA for Rayleigh channel*: Rayleigh fading channel with two users SISO has been assumed, considering 1000 samples under Monte Carlos approach for strong as well as weak users. The capacity of NOMA vs OMA has been observed for the different values of power coefficients. Figure 10 demonstrates that the output performance of NOMA is improved than OMA.

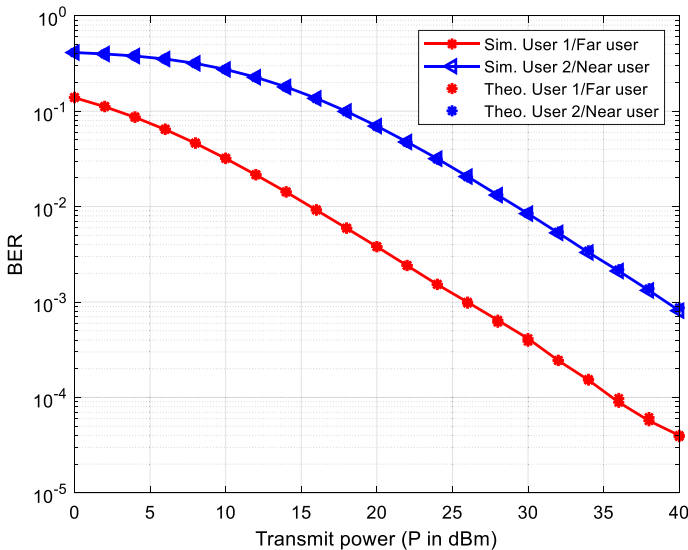


Fig. 9 NOMA-BER for Rayleigh channel

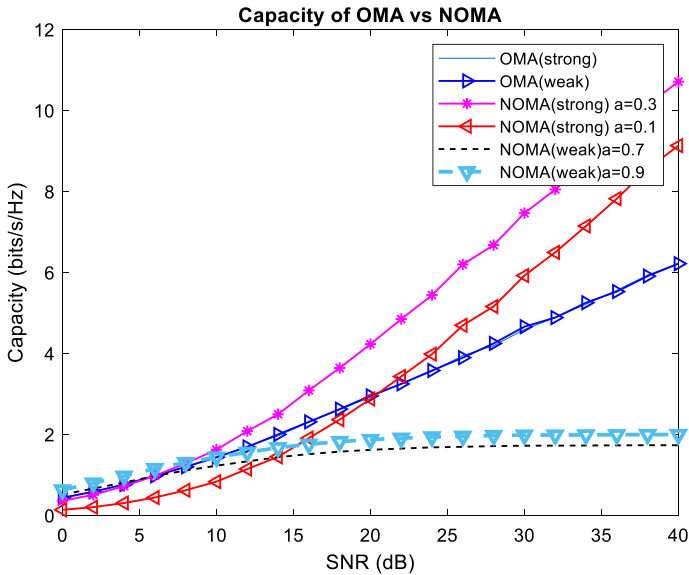


Fig. 10 Capacity of NOMA vs OMA for Rayleigh channel

8 Conclusion

In this survey, the latest literature for NOMA in 5G systems and beyond has been estimated with significance on the 5G advancement and upcoming innovations. The motivation behind the usage of NOMA as a prominent candidate for 5G and beyond has been discussed in detail considering the principle of NOMA, the concept of NOMA followed by the categories of power, and the code domain NOMA. Also, the comparison has been done for NOMA to the conventional OMA technique while discussing the superiority of NOMA over OMA. At last, the study centers around numerous open possibilities and difficulties that need to be routed to brand NOMA adaptable with additional up-and-coming communication standards, for example, mmWave communications, visible light communication, etc. All NOMA plans examined a similar soul of non-orthogonal transportations to improve the achievable bandwidth efficiency and to give availability to various users inside the predetermined values of RBs. Based on the above discussion and by employing non-orthogonality, 5G networks will offer enhanced throughput, improved spectral efficiency, and massive connectivity.

9 Future Work

This paper has examined several NOMA schemes. A common thread across different techniques has been their use of non-orthogonality to boost the capacity of the system and enable restricted RB to be used by more users. To develop the performance of NOMA systems, further research is required. The joined design of various modulations and NOMA schemes is a crucial way that needs to be researched in 5G networks. Also, the layout of

modulation and multiple access schemes for frequencies beyond 40 GHz is commencing to acquire improved interest. In mmWave and TeraHz band, high-level impairments such as phase noise, etc. should also be taken care of.

Funding We declare that there is no funding for this work.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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