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A Systematic Review of NOMA Variants for 5G and Beyond

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Abstract

With the fast expansion of the Internet of Things (IoT), there is an exponential need for mobile intelligent terminals .However, the connectivity of large-scale intelligent terminals is constrained by increasingly restricted spectrum resources. To address this issue, non-orthogonal multiple access (NOMA) technology, which can handle more users with less resources, is predicted to enable future wireless networks beyond 5G,., 6G, to give huge terminal access. The fundamental idea behind NOMA is to superimpose signals from numerous users on the same time-frequency resource prior to transmission. At the receiver, serial interference cancellation (SIC) technology is used to reduce interference among users. In this review paper we discusses the principles of the strong candidate Non-Orthogonal Multiple Access (NOMA) approach, as well as how it can best match the requirements of the Fifth Generation (5G) requirements in practical applications.

Keywords*:* beyond 5G/ (B5G) ; Non-orthogonal multiple access(NOMA);Superposition Coding (SC);Serial interference cancellation (SIC) ;NOMA Cooperative (C-NOMA).

I. Introduction

Sixth Generation (6G) wireless technology is a new wireless technology that many academics and researchers are working on. The promises of 6G are to expand AI and ML advantages in wireless networks and to consumers. 6G will also deliver breakthroughs in technical metrics like as high throughput, support for new high-demand apps, enhanced radio frequency band use, and many more leveraging AI and ML approaches[1] A

comprehensive concept of 5G wireless networks may be summarized as follows:

•A highly efficient mobile network that ensures optimal performance

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At a reduced investment rate, performance is improved. It should fulfill the very desirable necessity for a unit cost of data transmission that varies inversely with the volume of data needed, which is a critical need for mobile network operators.

•In the worst-case scenario, an ultra-fast mobile network comprised of the next generation of tiny cells firmly packed together to provide continual coverage throughout urban areas.

•Provide millimeter wave bands (20-60 GHz), which enable increased bandwidth and data access speeds of up to 10 G bit/s [2].

The enormous rise in mobile communications traffic has fueled research efforts in both academic and industry groups to develop the next generation (5G) of wireless networks capable of significantly improving coverage and user experience, 5G wireless networks necessitate very spectral-efficient multiple access approaches, which have a significant impact on the performance of mobile communication systems.Multiple access approaches can be classed as orthogonal or non-orthogonal based on how resources are assigned to users. [3]. In cellular networks, Orthogonal Numerous Access (OMA) systems such as Frequency Domain Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), and Orthogonal FDMA (OFDMA) have been used to service multiple users. Although OMA approaches are viable options for achieving strong system-level spectral efficiency with simple single user identification, they fall short of the broadcast channel's capacity(4) OMA is not always capable of matching the sum-rate capacity of multiuser wireless networks ,Aside from that, the maximum number of supported users in traditional OMA methods is restricted by the overall amount and scheduling granularity of orthogonal resources. Recently, NOMA has being researched to address the issues raised by OMA. NOMA, in essence, provides for regulated interferences through non-orthogonal resource allocation with a reasonable increase in receiver complexity[5]] NOMA, unlike classic orthogonal multiple access (OMA) methods, serve several users in the same time/frequency/code resource block (RB) and identify users with differing channel conditions in the power domain, where successive interference cancellation (SIC) is used at the receiver. It has been demonstrated that NOMA can produce greater throughput and lower latency than OMA[6]. Because of the usage of OMA, it is unavoidable that one of the few bandwidth resources will be entirely taken by this user, notwithstanding the poor channel circumstances. This obviously has a detrimental influence on the entire system's spectrum efficiency and throughput. In such a case, the adoption of NOMA assures not only that the user with bad channel conditions is serviced, but also that users with better channel circumstances can concurrently use the same bandwidth resources as the weak user ,Power can be freely allocated to each user in the downlink scenario, while each user has its own power restriction in the uplink situation. As a result, power allocation for uplink systems and downlink systems differ significantly, and power allocation techniques created for downlink systems cannot be used to uplink system[7] NOMA methods are widely classified into two types: PD-NOMA and code-domain NOMA, which includes low density spreading (LDS) and sparse code multiple access (SCMA)[8] In the power domain of NOMA systems, multi-user access to the same resource is implemented. As a result, the whole advantage of the NOMA system is dependent on optimal power allocation, which impacts not only the detection order at the receiver but also the overall performance. As a result, numerous experts have lately investigated power allocation for NOMA systems[9].

Table 1: shows the evolution of communication technology[9]

Generation	The Key Technologies	Services
1G	AMPS Analog	voice service
2G	GSM, TDMA, CDMA	Digital voice service
3G	‹WCDMA, CDMA2000 TD-SCDMA, Wi MAX	Simultaneous transmission of voice and data
4G	4G TD-LTE, FDD-LTE	Fast transmission of voice, data, video, image
5G	Millimeter Wave, Massive ‹MIMO, Micro Base Station, D2D Beam forming, NOMA	HD video, smart home, etc

III. Related work and existing surveys

The study in [10] Islam, SM Riazul, and his colleagues describes how NOMA works when paired with several known wireless communications methods, including cooperative communications, multiple-input multiple-(MIMO)forming, space-time coding, and network coding. Furthermore, this study output (MIMO), beam investigates a number of critical issues with NOMA implementation and suggests some future research directions. It also provides a high-level overview of several implementation challenges, such as computational complexity, error propagation, deployment environments, and standardization status. To summary, the results of this research have been useful to wireless communications and NOMA researchers. in [11] The fundamental idea and benefits of NOMA technologies, which are one of the promising technologies for future 5G networks, are presented in this study. NOMA lead charts are presented, as well as a comparison of its operating principles, major characteristics, receiver complexity, benefits and drawbacks,. encompassing theoretical analysis, the design of spreading sequences or codebooks, receiver design, access-grant-free NOMA design challenges, resource allocation systems, expansions to large-scale MIMOs, and so on. In [12], the researchers examine how NOMA is integrated with many other technologies for 5G wireless networks and beyond, such as sub-6 GHz and mm Wave Massive MIMO, Cognitive and Collaborative Connections, Physical Layer Security, Visible Light Communications, Energy Harvesting, mobile edge computing, and machine learning and deep learning. Zhu, Lipeng, and his colleagues In[13] explain the effect of beam forming on the sum-rate performance of mm Wave-NOMA is investigated, and it is discovered that with typical single-beam forming, the performance may be offset by the relative angle between NOMA users. Then, for mm Wave-NOMA, we explore multi-beam formation, which has been found to improve both performance and resilience. Following that, we look at the difficult joint design of the interlaced power allocation and user pairing for mm Wave-NOMA , Consider hybrid spatial division multiple access (SDMA) with NOMA in mm Wave communications, as shown in figure [1-2-.3] .

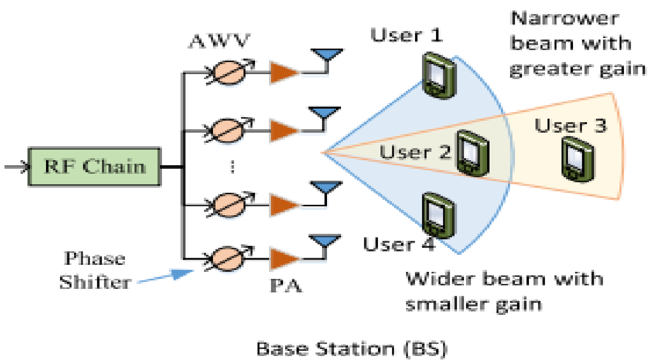

Figure 1: Mm wave-NOMA with analog beam forming at the bs9[13].

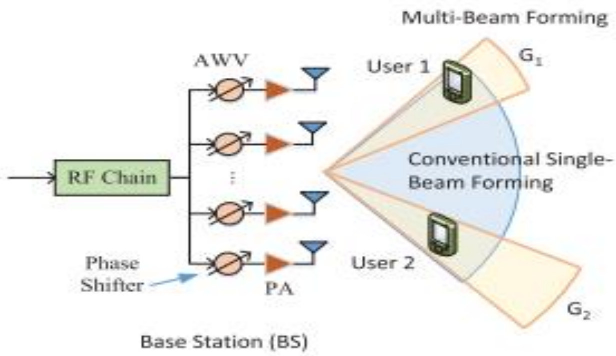

Figure 2:performance comparison between mm wave-NOMA with single

-beam forming and mm wave-TDMA[13]

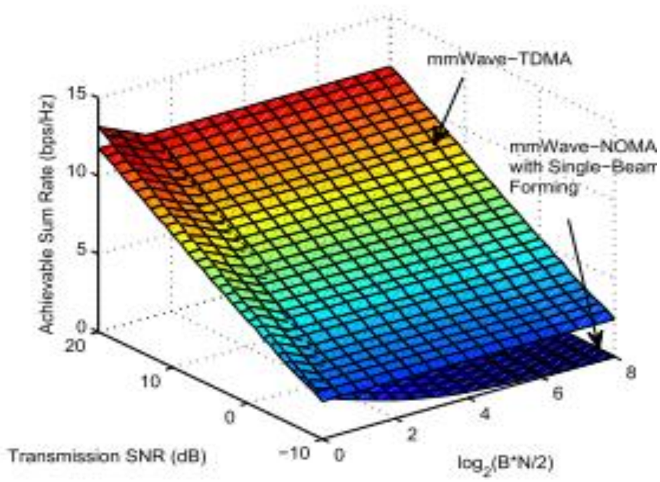

Figure3: Comparison between single-beam forming and multi-beam forming for mm wave-NOMA[13**]**

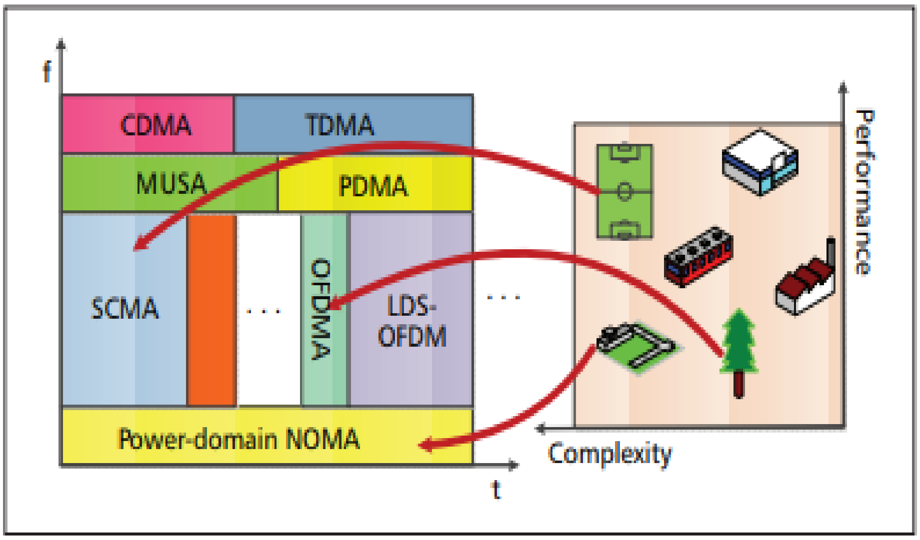

Figure 4: Illustration of the concept of software defined multiple access[14**]**

In[14] Dai, Linglong, et al studied concentrated on NOMA, which is supposed to boost the system's productivity and communication capabilities. It should be noted that the third generation partnership 3GPP Long Term Evolution (LTE) Rel-13 is conducting research toward NOMA, It takes the form of a multi-user overlay (must). Multiple users can share time and frequency resources at the same time at the spatial layer via an energy field or a symbol field Double. Many NOMA schemes have recently received a lot of attention, and they may be generally split into two groups, for example, power domain multiplexing and coding Multiple access with low-density proliferation (LDS) , sparse Code Multiple Access (SCMA) , multiple users Mutual Access (MUSA) , and other domain multiplexing techniques are used.

IV. NOMA system

In this part, we will quickly describe the essential principles of orthogonal multiple access (OMA) and NOMA. Traditional OMA methods include frequency-division multiple access (FDMA), time-division multiple access (TDMA), code-division multiple access (CDMA), and orthogonal frequency-division multiple access (OFDMA), which are used for 1G, 2G, 3G, and 4G, respectively. Multiple users are assigned to orthogonal radio resources in frequency, time, code-domain, or combinations**.** In FDMA, each user delivers a unique user-specific signal via its own unique frequency resource. As a result, the receiver can immediately identify all users' data in their appropriate frequency ranges ,Furthermore, with TDMA, each user is assigned a specific time slot; as a result, distinguishing between users' signals at time domain receivers is simple. Different users can share the same time-frequency resources in CDMA, whereas the

transmitted symbols of different users can be connected to orthogonal spreading sequences, such as Walsh-Hadamard codes. As a result, a low-complexity decorrelation receiver allows for the application of multi-user detection (MUD). OFDMA is an intelligent mix of FDMA and TDMA in which radio resources are orthogonally split in a time frequency grid [15]. The advantage of orthogonal resource allocation is that there is no interaction between OMA system users in theory, As a result, low-complexity indicators with linear complexity can assign various signals to different users. In typical OMA systems, the maximum number of viable users is severely constrained by the available number of orthogonal resources, resulting in less broad connectivity in 5G .Furthermore, it has been demonstrated that OMA cannot consistently achieve the maximum attainable sum-rate of multi-user wireless networks.

Unlike OMA approaches, NOMA may support many users by using time-sharing or rate-splitting as needed [16]. To solve the aforementioned restriction of OMA, NOMA was recently suggested as a viable alternative. The important feature of the NOMA system is the ability to sustain reliable communication for a large number of users that exceeds the number of orthogonal resource slots provided by non-orthogonal resource allocation [17], Complex inter-user interference cancellation can be achieved at the expense of increased receiver complexity, such as computational complexity with polynomial or exponential order. Using strong multiuser detectors to minimize interference is a useful method. NOMA systems are classified into two types: power-domain NOMA and code-domain NOMA. NOMA in the power domain implies varying power levels for unique users dependent on channel quality, as long as the same time-frequency-code resources are shared by many users. NOMA power-domain uses the power-difference between users to identify different users for successive interference cancellation (SIC) at the receiver side. The NOMA Code-domain is equivalent to CDMA or multi-carrier CDMA (MC-CDMA) unless it uses low-density or non-orthogonal sequences that have a low cross-.[correlation [18].

V. Comparison with OMA

Because of the orthogonal resource distribution in OMA, there should be no interference among numerous users, hence basic single-user detection may be employed to differentiate various users' signals. In theory, OMA cannot always attain the sum-rate capacity of multiuser wireless networks. Aside from that, the maximum number of supported users in traditional OMA methods is restricted by the overall amount and scheduling granularity of orthogonal resources. Recently, NOMA has being researched to address the issues raised by

OMA. NOMA, in essence, provides for regulated interferences through non-orthogonal resource allocation with a reasonable increase in receiver complexity. The following are the primary benefits of NOMA vs OMA:

- **Improved spectral efficiency*:*** Fig. 7 displays the channel capacity comparison of OMA and NOMA, using two users in the additive white Gaussian noise (AWGN) channel as an example without loss of generality, based on the multi-user capacity analysis in the pioneering work.

Figure 7a shows that uplink NOMA can reach the capacity constraint, but OMA systems are generally suboptimal, with the exception of point C. However, when the difference in the received

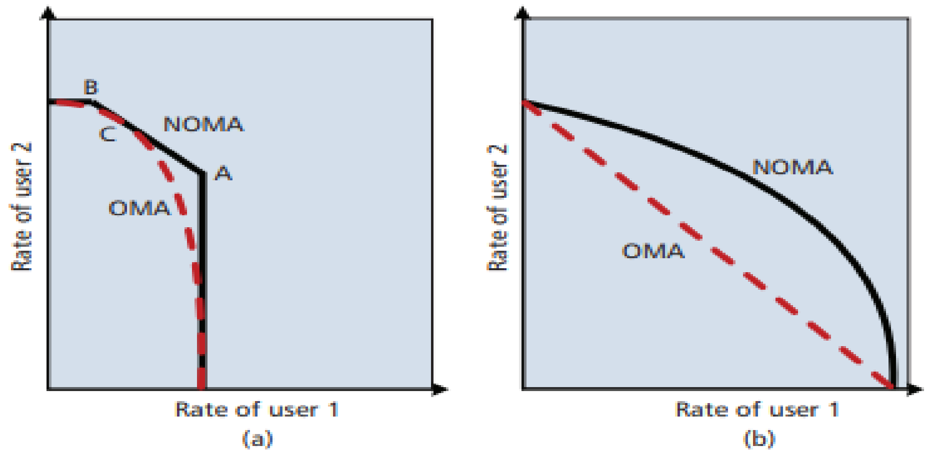

Figure 7: Shows a comparison of OMA and NOMA channel capacities in an AWGN channel:

a) AWGN uplink channel

b) AWGN downlink channel[19]

powers of the two users is large, the user throughput fairness is relatively bad at this optimal point, since the rate of the weak user is significantly lower than that of the strong user. Figure.7 b depicts the border of NOMA rate pairs in the downlink[1٩].

- **Massive connectivity:** The allocation of non-orthogonal resources in NOMA implies that the number of supportable users/devices is not rigidly restricted by the amount of orthogonal resources available. As a result, NOMA has the ability to greatly increase the number of simultaneous connections in rank-deficient settings. The ability to support huge connections. Of course, various actual implementation challenges in NOMA systems, such as hardware defects and computing complexity, may obstruct the realization of vast interconnection[20].
- **Low transmission latency*:*** Users in networks that employ OMA methods must wait for an available orthogonal resource block to give transmission access. NOMA systems, on the other hand, provide more flexible user scheduling options as well as grant-free transmission[21].

VI. NOMA types

In all NOMA systems, information from many users is sent on shared resources, and joint detection is to detect the signal. The receiver adapts a joint detection method, such as message .conducted at the receiver passing algorithm (MPA) or sequential interference cancellation (SIC), to identify non-orthogonal signals. While the fundamental premise of all NOMA schemes is the same, NOMA schemes are classified according to the domain in which non-orthogonality is accomplished. Different signature designs, such as spreading sequences, spreading codes, interleaver, and power allocation ratios, are used to distinguish users[22].

In low density spreading multiple access (LDS) [23] and Sparse code multiple access (SCMA) [24, 25], for example, information from a single user is spread across numerous subcarriers. User-specific spreading sequences, in particular, are utilized in LDS; these sequences are either sparse or non-orthogonally cross-correlated with a low correlation factor. The sparse characteristics guarantee that the same subcarrier is not used by a large number of users, keeping the system's complexity reasonable. The multidimensional codebook in SCMA is intended to validate that many users are effectively dispersed across subcarriers. At the transmitter, bit spreading and bit mapping are merged, and input data bits are immediately translated to multidimensional codebook code-words. Because a user's message is jointly encoded at various subcarriers at the transmitter, joint decoding is necessary at the receiver, which MPA realizes.Multiplexing in numerous domains, including spatial, is possible using pattern division multiple access (PDMA) [26].code, or sphere of authority. No orthogonal patterns are used at the transmitter to reduce user overlapping. The pattern matrix, also known as the subcarrier allocation matrix, governs the dispersion of many users. MPA may be extended to detect spread information at the receiver, and MPA-SIC is used when users are multiplexed on both the power and space domains. Inter-leavers distinguish various users in interleave-division multiple-access (IDMA) [27]. Extra bandwidth and memory resources are required at the transmitter and receiver due to the interleaver. To improve performance, an elementary signal estimator with or without iteration is utilized at the receiverMultiplexing in PD-NOMA is done in the power domain. At the transmitter, signals from multiple users are superposed by assigning optimal power to each user, and the succeeding signal is delivered using the same subcarriers. Table 2 summarizes the many forms of NOMA outlined previously.

Table 2: Summary of types of non-orthogonal multiple access schemes[27]

NOMA type	Multiplexing domain	Receiver type	Advantages	Disadvantages
LDS	Spreading codes	MPA	Channel state information (CSI) is not required	Coding causes redundancy
SCMA	Codebooks	MPA	Channel state information (CSI) is not required , Good performance	Complex detection/decoding, Limited number of code words may lead to collision (when user share same resources)
PDMA	Pattern	SIC/MPA	Good performance	Low overload,

				High complexity for MPA receiver
IDMA	Interleaver	Elementary signal estimation with/without iterative detection	High user overload High spectral efficiency	High latency in case of iterative detection, Extra signaling for channel detection
Powerdomain NOMA	Power	SIC	High performance Less receiver complexity	Error propagation, Low user overloading because user pairing is required

VII. Principle OF NOMA

A. Superposition Coding (SC)

The SC, initially suggested in [28], is a method of concurrently conveying information to multiple receivers from a single source. In other words, it enables the transmitter to send data from several users at the same time. Examples of superposed communications include sending a television signal to many receivers and delivering a speech to a group of individuals with diverse backgrounds and abilities. For example, a classroom lecture. Assume a professor is delivering knowledge to students in the form of a lecture in the classroom. Due to variances in the characteristics and histories of the pupils, some receive the majority of the material while others acquire only a portion of it. The lecture can be structured such that it moves at the pace of the student with the least extensive experience. However, in an ideal circumstance, the lecture may be arranged so that the students with the most appropriate background receive more information and the poor students receive at least the bare minimum of knowledge. This is an example of a broadcast channel in which the speaker is delivering a superposed lesson. To make SC work, the transmitter must encode information specific to each user. In a two-user case, for example, the transmitter must have two point-to-point encoders that translate their respective inputs to complex-valued sequences of the two-user signal. A schematic diagram of SC is shown in Fig. 8, where the quadrature phase-shift keying (QPSK) constellation of user 1 with higher transmitting power is superposed on that of user 2 with lower transmitting power. It should be noted that SC is a well-known non-orthogonal technique that achieves capacity on a scalar Gaussian broadcast channel. Vanka et al. proposed effective SC techniques [29].

B. Successive Interference Cancellation (SIC)

Cover initially suggested the SIC approach [30] to decode the superposed information at each receiver. SIC is possible by utilizing parameters on signal strength disparities among the signals of interest. The core notion behind SIC is that user signals are decoded sequentially. The signals of interest are removed from the combined signal before the next user's signal after one user's signal has been decoded. The core notion behind SIC is that user signals are decoded sequentially. After decoding one user's signal, it is removed from the combined signal before decoding the next user's signal. When SIC is used, one of the user signals is decoded while the other is treated as an interferer, but the latter is subsequently decoded with the advantage of the former's signal already being eliminated. Prior to SIC, however, users are arranged by signal strength so that the receiver may decode the stronger signal first, remove it from the combined signal, and isolate the weaker signal from the remainder. It should be noted that each user is decoded while the other interfering users are treated as noise in signal reception, The approach for decoding the superposed signal (Fig. 8) at the receiving side is shown in(Fig. 9)

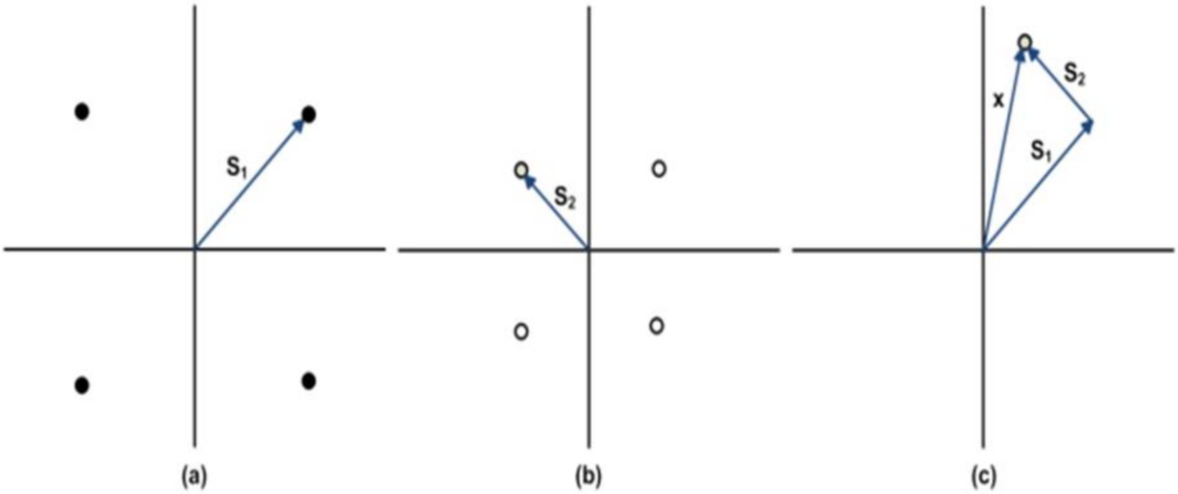

Figure 8: An Example Of SC Encoding

(a) Signal constellation of user 1

(b) Signal constellation of user 2

(c) Constellation of superposed signal[29]

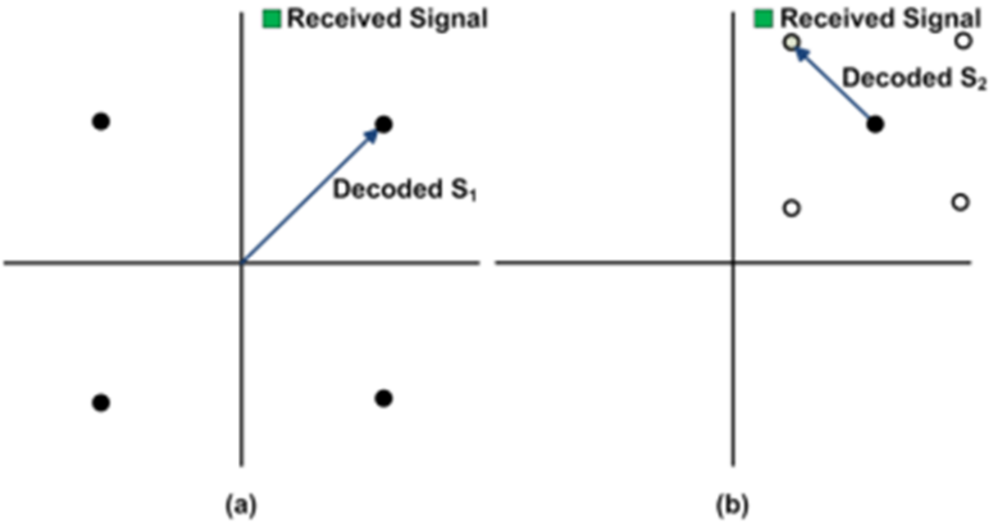

Figure9: An example of SC decoding

(a) Decoding the signal of user 2 (b) Decoding the signal of user 1[30]

VIII. NOMA cooperative (C-NOMA)

Because of the appealing features, significant research has been performed to implement NOMA methods for diverse systems and applications. In accordance with this, cooperative NOMA (C-NOMA) is one of the most active research areas. By utilizing the preceding knowledge accessible in a NOMA system, the notion of a C-NOMA scheme in the form of a downlink system was originally introduced in [31]. First, present the fundamental form of a C-NOMA. Then, certain C-NOMA versions are discussed:

- **Basic C-NOMA:** Consider a downlink NOMA system with one BS and K users as an example of basic C-NOMA. The CNOMA described in [31] operates in two stages. The BS transmits the superposed message to the K users during the first phase, known as the direct transmission phase, by superposing K messages using the NOMA principle. The communications will then be deciphered by the users. Except for user K, SIC will be conducted by all users (the weakest user). During the second phase, known as the cooperative phase, users collaborate with one another via short-range communication protocols like as Bluetooth and ultra-wideband. This phase is made up of (K -1) time s However, cooperative NOMA is not feasible since user involvement requires a high level of processing complexity, and the additional time slots would increase communication latency. Thus, user grouping can be used to mitigate the impact. As a result, users in a cell might be separated into many groups. Then, within each group, C-NOMA can be used independently lots.
- **Cooperative Relaying Scheme-based NOMA (CRS-NOMA):** NOMA based on the Cooperative Relaying Scheme (CRS-NOMA): Because the strongest user at each time slot in the cooperative phase functions as a relay for other users, the C-NOMA notion outlined above may be considered as relay-assisted NOMA. Indeed, cooperative relaying systems that take use of geographical variety are a popular communication paradigm [32]. The destination in a cooperative relaying system receives and combines two independent copies of the same broadcast signal, one directly from the source and the other from the relay, using a half-duplex relay. As a result, the total SINR at the receiver increases, improving signal reception quality. However, due to transmission duplication, cooperative relaying suffers from a spectrum efficiency loss. As a result, a cooperative relaying system (CRS) based on NOMA, known as CRS-NOMA, was developed, is presented as a means of improving overall spectral efficiency [33] The source transmits the superposition coded signal in the first time slot in the CRS-NOMA. The relay then conducts SIC and decodes its own symbol as well as the symbol to be sent to the destination.
- **Uplink and Downlink C-NOMA:** An intriguing cooperative relaying utilizing NOMA has been discovered studied in [34], in which many sources employ a shared relay to send their messages to their various destinations at the same time. In this technique, the relay receives the transmitted symbols from

the sources in an uplink NOMA way before broadcasting the superposition coded signal to the destinations in a downlink NOMA manner. In this regard, [34] makes use of both uplink and downlink NOMA ideas to attain a greater ergodic capacity in a cooperative setting .

The spectral efficiency of the cooperative phase of the combined uplink and downlink NOMA can be increased further by broadcasting a new symbol from the source to the destination [35]. As a result, a source broadcasts the superposing coded signal to a destination and relay in downlink NOMA mode during the first phase. Following the uplink NOMA concept, the source concurrently transmits a new symbol for the destination while the relay passes the SIC-decoded signal to the destination.

X. NOMA and physical layer security

Because wireless communications are broadcast, protecting transmitted data from any external eavesdroppers and Internal eavesdroppers (untrusted nodes in the network)a vital system design feature that must be carefully considered. PHY security is an effective strategy for achieving the objective of a communication system that is shown to be impenetrable.

Connections between nodes to .PHY security solutions take use of the physical characteristics of communication provide security to wireless systems of communication. Several PHY security techniques are now available to ensure safe communication in the setting of a wiretap channel. Some can provide security even if the legitimate user's channel is inferior than the eavesdropper's channel. Among these are artificial noise (AN) transmission [36], various beam forming algorithms [37]-[38], transmit antenna selection [39]-[40], cooperative jamming, and relay-based PHY security solutions [41]-[42]

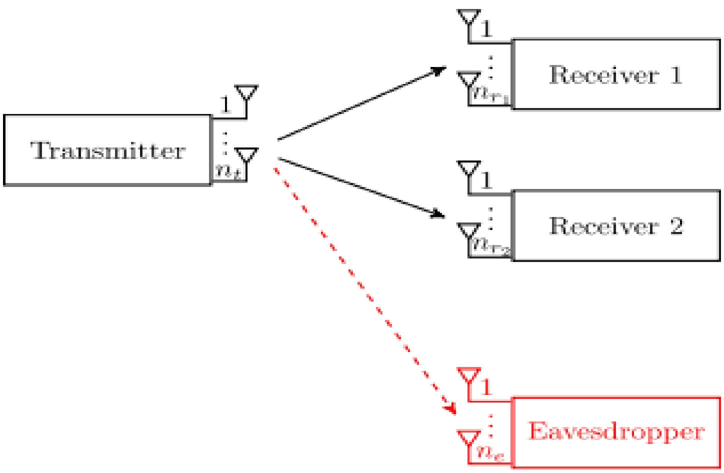

Figure10: Depicts a two-user MIMO-NOMA with an external eavesdropper[42]

XI. Power allocation in NOMA

Because users are multiplexed in the power domain, power allocation is critical in NOMA [43]. It is directly related to Interference management, rate distribution, and even user admission all have an influence on system performance. An ineffective PA may result not only in an uneven rate allocation among customers, but also in a system outage due to SIC failure. When building PA methods, users' channel circumstances, CSI availability, quality of service QoS requirements, total power constraint, system aim, and so on must all be taken into account. The number of allowed users, total rate, energy efficiency, user fairness, and other commonly used PA performance measures include The chance of a power outage and overall power use. As a result, the goal of PA in NOMA is either to achieve more admitted users, a higher sum rate, and energy efficiency (EE), or to achieve balanced fairness while utilizing the least amount of power

Figure 11 displays a classification of PA strategies proposed in the literature to address certain aspects of PA in NOMA. PA: One focuses on single-carrier (SC) systems, while the other focuses on multi-carrier (MC) systems.

Figure 11: Classification of PA[43]

XII. Practical considerations of massive NOMA for massive cellular IOT and future directions

Although NOMA can enhance spectrum efficiency and system capacity, there are several practical problems that must be overcome before this technology can be deployed in actual wireless networks for M2M communications. We explain the key practical considerations of huge NOMA for M2M communications in this section:[44]

- **Base station traffic and load estimation**: Because devices choose sub bands at random for data transmission, the base station must precisely estimate the number of devices transmitting across each sub band. One method is to use power regulation at the devices such that the received power over each sub band is proportionate to the number of devices transmitting over that sub band. This is covered in further depth in the following sections..
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- **Channel estimation and power allocation:** Because so many devices desire to communicate with the base station at the same time, it is nearly difficult for the base station to estimate the channel to all of these devices. When several antennas are utilized in either the devices or the base station, the situation gets more difficult. Because the channel between each device and the base station is reciprocal in both directions (as in time division duplexing), the devices can estimate their channel to the base station using the pilot signal broadcasted by the base station on a regular basis and then adjust their transmission power so that the received signal power at the base station is the same fixed value for each device.
- **Device synchronization:** Because the devices in random NOMA are recognized during data transmission, the base station cannot derive the time advance information for each device. One possibility is that the devices will estimate their time information based on prior broadcasts or on their location information, which is more realistic in M2M applications with fixed position devices. Providing temporal synchrony amongst a large number of devices is a difficult task that necessitates significant technical effort.
- **Proper channel code design:** The number of devices transmitting in the same sub band determines the effective data rate for each device. Because the devices choose a sub band at random for data transmission, the number of devices broadcasting over each sub band is unknown in advance. This implies that the coding rate at which each device's data should be sent is not defined. One method is to employ rate less codes, in which the devices send using a rate less code and then cease transmitting once they receive an acknowledgement from the base station. This has been examined in [45], however one must consider the random structure of rate less codes and provide a method to swap the random graph structure between the base station and the devices.
- **SIC Complexity**: In current orthogonal techniques, the BS must decode each device separately, but with the proposed NOMA, the same decoder may be used for all devices Used for all devices in a consecutive order. However, at the decoder, we can consider a separate decoder for each device and decode each device while treating the signal from all other devices as additive noise. This may degrade throughput marginally, but the deterioration may be ignored because the attainable rate is mostly governed by the device with the lowest SINR at the BS. For further information on the SIC procedure, interested readers may consult [45].
- **User fairness**: The BS can provide more bandwidth to devices that have a low-quality link to the BS, allowing them to communicate with less power. This manner, devices with low quality connections can transmit with less power across a greater bandwidth and achieve the same throughput or energy efficiency as devices with high quality links sending over a narrower bandwidth or with more power.

V.Conclusions

In this review paper, we have discussed the main concept of NOMA technologies, which constitute one of the promising technologies for future 5G systems. The different types of NOMA charts are presented along with the advantages of the system compared to the orthogonal OMA system. We have highlighted future studies and research related to NOMA design and the NOMA Collaborative Association (C-NOMA)., and Physical Layer structure and so on .Finally, we highlight practical considerations for massive NOMA for massive cellular IOT and future directions. NOMA is predicted to play a significant role in future 5G wireless communication systems, enabling huge connectivity and minimal latency.

References

[1] Kaur, J., Khan, M. A., Iftikhar, M., Imran, M., & Haq, Q. E. U. (2021). Machine learning techniques for 5G and beyond. *IEEE Access*, *9*, 23472-23488.

[2] Kassir, A., Dziyauddin, R. A., Kaidi, H. M., & Izhar, M. A. M. (2018, July). Power domain non orthogonal multiple access: A review. In *2018 2nd International Conference on Telematics and Future .Generation Networks (TAFGEN)* (pp. 66-71). IEEE.

[3] Dai, L., Wang, B., Ding, Z., Wang, Z., Chen, S., & Hanzo, L. (2018). A survey of non-orthogonal .multiple access for 5G. *IEEE communications surveys & tutorials*, *20*(3), 2294-2323.

[4] Parida, P., & Das, S. S. (2014, December). Power allocation in OFDM based NOMA systems: A DC programming approach. In *2014 IEEE globecom workshops (GC Wkshps)* (pp. 1026-1031). IEEE.

[5] Dai, L., Wang, B., Yuan, Y., Han, S., Chih-Lin, I., & Wang, Z. (2015). Non-orthogonal multiple access for 5G: solutions, challenges, opportunities, and future research trends. *IEEE Communications .Magazine*, *53*(9), 74-81.

[6] Liaqat, M., Noordin, K. A., Abdul Latef, T., & Dimyati, K. (2020). Power-domain non orthogonal multiple access (PD-NOMA) in cooperative networks: an overview. *Wireless Networks*, *26*, 181-203.

[7]] Ding, Z., Lei, X., Karagiannidis, G. K., Schober, R., Yuan, J., & Bhargava, V. K. (2017). A survey on non-orthogonal multiple access for 5G networks: Research challenges and future trends. *IEEE Journal on Selected Areas in Communications*, *35*(10), 2181-2195.

[8] Tian, X., Huang, Y., Verma, S., Jin, M., Ghosh, U., Rabie, K. M., & Do, D. T. (2020). Power allocation scheme for maximizing spectral efficiency and energy efficiency tradeoff for uplink NOMA systems in B5G/6G. *Physical Communication*, *43*, 101227.

[9] Zhang, J., Zhu, L., Xiao, Z., Cao, X., Wu, D. O., & Xia, X. G. (2019). Optimal and sub-optimal uplink NOMA: joint user grouping, decoding order, and power control. *IEEE Wireless Communications*

Letters, *9*(2), 254-257.

[10] Islam, S. R., Avazov, N., Dobre, O. A., & Kwak, K. S. (2016). Power-domain non-orthogonal multiple access (NOMA) in 5G systems: Potentials and challenges. *IEEE Communications Surveys & Tutorials*, *19*(2), 721-742.

[11] Dai, L., Wang, B., Ding, Z., Wang, Z., Chen, S., & Hanzo, L. (2018). A survey of non-orthogonal multiple access for 5G. *IEEE communications surveys & tutorials*, *20*(3), 2294-2323.

[12] Vaezi, M., Baduge, G. A. A., Liu, Y., Arafa, A., Fang, F., & Ding, Z. (2019). Interplay between NOMA and other emerging technologies: A survey. *IEEE Transactions on Cognitive Communications and Networking*, *5*(4), 900-919.

[13] Zhu, L., Xiao, Z., Xia, X. G., & Wu, D. O. (2019). Millimeter-wave communications with non-.orthogonal multiple access for B5G/6G. *IEEE access*, *7*, 116123-116132.

[14] Dai, L., Wang, B., Yuan, Y., Han, S., Chih-Lin, I., & Wang, Z. (2015). Non-orthogonal multiple access for 5G: solutions, challenges, opportunities, and future research trends. *IEEE Communications Magazine*, *53*(9), 74-81.

[15] Xiong, C., Li, G. Y., Zhang, S., Chen, Y., & Xu, S. (2012). Energy-efficient resource allocation in OFDMA networks. *IEEE Transactions on Communications*, *60*(12), 3767-3778.

[16] Ali, M. S., Tabassum, H., & Hossain, E. (2016). Dynamic user clustering and power allocation for uplink and downlink non-orthogonal multiple access (NOMA) systems. *IEEE access*, *4*, 6325-6343.

[17] Islam, S. R., Zeng, M., Dobre, O. A., & Kwak, K. S. (2018). Resource allocation for downlink NOMA systems: Key techniques and open issues. *IEEE Wireless Communications*, *25*(2), 40-47.

[18] Gau, R. H., Chiu, H. T., & Liao, C. H. (2020). A geometric approach for optimal power control and relay selection in NOMA wireless relay networks. *IEEE Transactions on Communications*, *68*(4), 2032-2047.

[19] Dai, L., Wang, B., Yuan, Y., Han, S., Chih-Lin, I., & Wang, Z. (2015). Non-orthogonal multiple access for 5G: solutions, challenges, opportunities, and future research trends. *IEEE Communications Magazine*, *53*(9), 74-81.

[20] Dai, L., Wang, B., Ding, Z., Wang, Z., Chen, S., & Hanzo, L. (2018). A survey of non-orthogonal .multiple access for 5G. *IEEE communications surveys & tutorials*, *20*(3), 2294-2323.

[21]] Maraqa, O., Rajasekaran, A. S., Al-Ahmadi, S., Yanikomeroglu, H., & Sait, S. M. (2020). A survey of rate-optimal power domain NOMA with enabling technologies of future wireless networks. *IEEE .Communications Surveys & Tutorials*, *22*(4), 2192-2235.

[22] Liaqat, M., Noordin, K. A., Abdul Latef, T., & Dimyati, K. (2020). Power-domain non orthogonal multiple access (PD-NOMA) in cooperative networks: an overview. *Wireless Networks*, *26*, 181-203.

[23] Mohammed, A. I., Imran, M. A., Tafazolli, R., & Chen, D. (2012, August). Performance evaluation of low density spreading multiple access. In *2012 8th international wireless communications and mobile computing conference (IWCMC)* (pp. 383-388). IEEE.

[24] Nikopour, H., & Baligh, H. (2013, September). Sparse code multiple access. In *2013 IEEE 24th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications .(PIMRC)* (pp. 332-336). IEEE.

[25] Taherzadeh, M., Nikopour, H., Bayesteh, A., & Baligh, H. (2014, September). SCMA codebook design. In *2014 IEEE 80th vehicular technology conference (VTC2014-Fall)* (pp. 1-5). IEEE.

[26] Zeng, J., Li, B., Su, X., Rong, L., & Xing, R. (2015, October). Pattern division multiple access (PDMA) for cellular future radio access. In *2015 international conference on wireless communications .& signal processing (WCSP)* (pp. 1-5). IEEE.

[27] Akbil, B., & Aboutajdine, D. (2015). Improved IDMA for multiple access of 5G. *International Journal of Communication Networks and Information Security*, *7*(3), 138.

[28] Cover, T. (1972). Broadcast channels. *IEEE Transactions on Information Theory*, *18*(1), 2-14.

[29] Vanka, S., Srinivasa, S., Gong, Z., Vizi, P., Stamatiou, K., & Haenggi, M. (2012). Superposition coding strategies: Design and experimental evaluation. *IEEE Transactions on Wireless Communications*, *11*(7), 2628-2639.

[30] Cover, T. (1972). Broadcast channels. *IEEE Transactions on Information Theory*, *18*(1), 2-14.

[31] Ding, Z., Peng, M., & Poor, H. V. (2015). Cooperative non-orthogonal multiple access in 5G systems. *IEEE Communications Letters*, *19*(8), 1462-1465.

[32] Laneman, J. N., Tse, D. N., & Wornell, G. W. (2004). Cooperative diversity in wireless networks: Efficient protocols and outage behavior. *IEEE Transactions on Information theory*, *50*(12), 3062-3080.

[33] Kim, J. B., & Lee, I. H. (2015). Capacity analysis of cooperative relaying systems using non-orthogonal multiple access. *IEEE Communications Letters*, *19*(11), 1949-1952.

[34] Kader, M. F., Shahab, M. B., & Shin, S. Y. (2017). Exploiting non-orthogonal multiple access in cooperative relay sharing. *IEEE Communications Letters*, *21*(5), 1159-1162.

[35] Kader, M. F., Uddin, M. B., Islam, S. R., & Shin, S. Y. (2019). Capacity and outage analysis of a dual-hop decode-and-forward relay-aided NOMA scheme. *Digital Signal Processing*, *88*, 138-148.

[36] Goel, S., & Negi, R. (2008). Guaranteeing secrecy using artificial noise. *IEEE transactions on wireless .communications*, *7*(6), 2180-2189.

[37] Fakoorian, S. A. A., & Swindlehurst, A. L. (2012, July). Optimal power allocation for GSVD-based beamforming in the MIMO Gaussian wiretap channel. In *2012 IEEE International Symposium on Information Theory Proceedings* (pp. 2321-2325). IEEE.

[38] Vaezi, M., Shin, W., & Poor, H. V. (2017). Optimal beamforming for Gaussian MIMO wiretap channels with two transmit antennas. *IEEE Transactions on Wireless Communications*, *16*(10), 6726-.6735.

[39] Ferdinand, N. S., da Costa, D. B., & Latva-aho, M. (2013). Effects of outdated CSI on the secrecy performance of MISO wiretap channels with transmit antenna selection. *IEEE Communications .Letters*, *17*(5), 864-867.

[40] Alves, H., Souza, R. D., Debbah, M., & Bennis, M. (2012). Performance of transmit antenna selection .physical layer security schemes. *IEEE Signal Processing Letters*, *19*(6), 372-375.

[41] Dong, L., Han, Z., Petropulu, A. P., & Poor, H. V. (2009). Improving wireless physical layer security .via cooperating relays. *IEEE transactions on signal processing*, *58*(3), 1875-1888.

[42] Li, J., Petropulu, A. P., & Weber, S. (2011). On cooperative relaying schemes for wireless physical .layer security. *IEEE transactions on signal processing*, *59*(10), 4985-4997.

[43] Vaezi, M., & Vincent Poor, H. (2019). NOMA: An information-theoretic perspective. *Multiple access techniques for 5G wireless networks and beyond*, 167-193.

[44] Islam, S. M., Zeng, M., & Dobre, O. A. (2017). NOMA in 5G systems: Exciting possibilities for .(enhancing spectral efficiency. *arXiv preprint arXiv:1706.08215*.

[45] Shirvanimoghaddam, M., Dohler, M., & Johnson, S. J. (2017). Massive non-orthogonal multiple .access for cellular IoT: Potentials and limitations. *IEEE Communications Magazine*, *55*(9), 55-61.