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Signal Processing based Iterative Channel Estimation Techniques for Noma-OFDM Systems

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Abstract

Interference has recently been a significant barrier to effectively implementing the 5G wireless network that supports various end-user applications. Many communication standards, as well as protocols, have been created and put to use throughout this time. It has been determined from the available literature that Non-Orthogonal Multiple Access (NOMA) can address the majority of the problems with the current solutions. In this study, we give an overview of the basics of NOMA, the current 5G enabling technologies that support NOMA, the classification of multiple access systems, and channel estimation approaches in NOMA. Future generation networks have been acknowledged to benefit from the NOMA method. To achieve greater spectral efficiency (SE), the orthogonal frequency division multiplexing (OFDM) technique could be combined with the NOMA system. We comprehensively compare the existing NOMA papers based on channel estimation, the algorithm used, the wireless system, the coding technique, and the modulation scheme. We also go into considerable detail about the primary distinctions between 5G Orthogonal Multiple Access (OMA) and NOMA. Several unresolved issues and research difficulties with NOMA-based systems are also examined.

Keywords: NOMA, OMA, OFDM, 5G, Channel Estimation.

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1. Introduction

A significant amount of data traffic is produced by accelerating expansion and use of smart technologies, including smartphones, wearable technology, sensors, streaming live, AR, VR, real-time video chat, video conference, and social media services. It puts an excessive load on long-term evolution (LTE). According to Cisco's 2017 Annual Internet Report research and estimate, there will be more than three times as many networked devices as people on Earth by 2025. Machine-to-machine links will make up about half of all connections worldwide. Several research groups are eager to employ beyond 5G networking to solve this issue and give end consumers a higher level of service quality (QoS) and experience quality (QoE). Therefore, effective multiple access (MA) methods are needed. In cellular networks, MA is used to share time and frequency resources across several active user equipments (UEs) making service requests [1].

Among the greatest vital elements in the process of improving the capacity of the system is the creation of a suitable MA approach, Orthogonal Multiple Access (OMA) and Non-Orthogonal Multiple Access (NOMA) are two types of MA methods [2]. Out of these two, OMA cannot resolve the mentioned problem for the reasons listed; i) because each user only receives one orthogonal resource block (RB), there is bandwidth waste, ii) Excessive signaling costs and inefficient access. Thus, one RB in the NOMA protocol can serve multiple users, and a user can use several RBs to increase its data rate. User signals are demultiplexed on the receiving end using the successive interference cancellation (SIC) approach after being multiplexed utilizing superposition coding (SC) at the transmitter side. The SC improves the scheduling, user fairness, and sum rate. Also, the SIC can nullify the inter-user interference that SC multiplexing causes. NOMA is typically categorized into Code-domain (CD-NOMA) and Power-domain (PD-NOMA). Many users are serviced from a single orthogonal RB in PD-NOMA strategically depending on the channel conditions. In CD-NOMA, in contrast, several users are served by the code spreading sequences.

2. 5G enabling technologies and NOMA

A major improvement in spectral efficiency (SE), user equality, widespread connectivity, lower latency, a larger coverage area, increased capacity, faster data rates, and enhanced performance are all possible, thanks to NOMA, combined with important 5G advanced technology. The existing and emerging 5G technologies are shown in the Figure 1 below.

2.1 HetNets and NOMA

The growth of smart gadgets has led to an increase in network traffic. Spectrally efficient technologies are required given the load on network bandwidth. One such technique is HetNets [3], which entails the addition of numerous low-power small cells to an infrastructure already composed of high-power macro cells. Better extended coverage area [4], higher capacity of a network, improved QoS, increased connection, and efficient use of the spectrum through

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frequency reuse over much smaller territories are all advantages of this cell densification strategy [5].

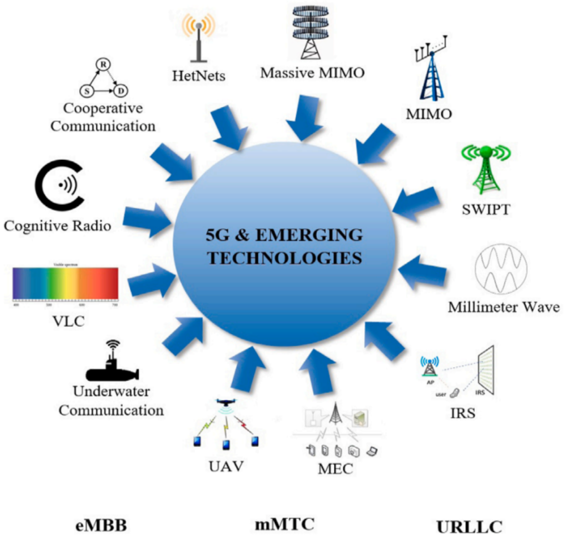


Fig. 1. 5G Emerging and Existing Technologies

Considering that both NOMA and HetNet are spectrally efficient and increase capacity, combining them is a good strategy for 5G and future-generation networks. NOMA's concept of user pairing can help connect even more devices improving the system's throughput.

2.2 MIMO-NOMA

Most of the NOMA research in the early years focused on a single antenna. Later, the MIMO approach was used by NOMA to increase its effectiveness improvements and acquire an additional degree of spatial freedom in addition to the power domain. According to the spatial multiplexing order of MIMO, the interaction between these two cutting-edge technologies, also known as MIMO-NOMA, may further increase the spectrum utilization benefit of NOMA. It is already documented in the literature that in single antenna system, comparing capacity, NOMA performs better than OMA. There is no such capacity proof, although, for the combination of MIMO with both OMA and NOMA. The authors in [6] critically show that MIMO-NOMA performs better than MIMO-OMA in the case of two users per cluster concerning ergodic sum capacity and sum channel capacity. In terms of ergodic total capacity and sum channel capacity, Zeng et al. analytically more thoroughly show the superiority of MIMO-NOMA over MIMO-OMA when multiple users are considered in a cluster [7]. Research indicates that when more users are added to a cluster, the sum rate decreases. Therefore, it is necessary to maintain a trade-off between the number of customers accepted and the sum rate.

The demand for resources and spectrum utilization is skyrocketing due to the fast rise of connected devices. There is an urgent need to explore new spectral regions because the frequency range of 0.3 to 3 GHz is dispersed and over-saturated. Utilizing untapped bandwidth above 3 GHz for millimeter wave communication enables high data speeds, improved capacity, dependability, and seamless connectivity. By using directional antennas at the sending and receiving ends, it is possible to overcome the propagation and penetration loss that millimeter wave communication experiences. Millimeter wave communication and many types of antenna technology like massive MIMO and MIMO can be coupled to meet 5G data requirements [8,9]. The required wavelength for antenna size diminishes, similar to a millimeter wave, allowing for the utilization of numerous miniature antennas at the sending and receiving end. As a result, route loss is decreased and directional antenna gain is greatly increased [10,11]. Typically, the number of RF chains and antennas are equivalent. However, compared to the number of antennae, only a few RF chains are on hand at each BS in millimeter wave communications due to increased power consumption and higher operational costs. Thus, fewer users are serviced as a result. A dense network with many users can have its SE further increased by integrating NOMA with millimeter wave MIMO, which also improves capacity, mass connectivity, and how the system operates [12–14]. It makes sense and is preferred to combine NOMA and millimeter wave MIMO because directional transmission ensures a good correlation between user channels, which in NOMA, is advantageous for user pairing. Due to expensive expenses, a millimeter wave BS is restricted to having fewer RF chains. In millimeter wave NOMA systems, the massive connection is enabled by the intrinsic NOMA feature that allows several users to share the same time and frequency blocks simultaneously.

Additionally, NOMA-enabled millimeter wave MIMO communication may meet the various needs of 5G network users while enhancing SE through SIC[15].

2.3 Massive MIMO-NOMA

By aggressively adopting spatial multiplexing, massive MIMO is a spectrally efficient, dependable, energy-efficient, and capacity-increasing technology that can handle the exploding needs for data usage. According to research, massive MIMO-OMA can sustain under-loaded systems—with fewer users than or the same number of antennas at the base station—but not overloaded ones. This problem is resolved and improved performance with mass connection is provided by the merging of massive MIMO and NOMA [16].

In addition to enabling untapped spectrum over 3 GHz to fulfill the constantly increasing connection, resource, and 5G data rate requirements, ultra-high frequency of millimeter wave communications significantly reduce the physical requirements for antennas placed at the transceivers. This opens the door for massive MIMO, which combines millimeter wave technology with huge antenna arrays. By combining these two popular 5G technologies, which take advantage of the vast amounts of unutilized millimeter wave spectrum and the significant multiplexing gain possible with massive MIMO, the prospective advantages of the system's performance and higher throughput are promised [9]. The quantity of RF chain employed in such settings is constrained due to power use restrictions and equipment expense restrictions, which lowers the group of individuals being served. NOMA with Millimeter Wave Massive MIMO is the result of the merging of massive MIMO, NOMA, and millimeter wave communication which is an important study topic recently to address these challenges. It is anticipated that this combination will enhance SE, system throughput, and practicable capacity gain [17].

2.4 Cognitive radio networks NOMA

The demand for spectrum utilization is rising along with the number of wirelessly linked devices; one such idea that might be used with NOMA to improve the SE of the network is Cognitive Radio (CR). Mitola [18] is credited with initially introducing the idea of CR. Spectrum sharing is the practice of numerous users in a given region simultaneously using a particular radio frequency spectrum. CRs are wireless, smart devices that dynamically alter their radio settings based on the radio environment. The CR allows unlicensed SUs to opportunistically access the licensed PUs' frequency spectrum to overcome the frequency scarcity. The interweave, underlay, and overlay modes are the three modes in which CRs commonly work. When a free frequency slot exists in the PU spectrum, SU broadcasts using an interference-controlling technique known as interweave. In the overlay, the SU cooperates with the PU to relay its data, and as payment, the SU transmits in the licensed user spectrum. Information from the PU is also used to lessen interference. Underlay mode is an interference-avoiding strategy since PU and SU broadcast concurrently however constrained through interference power constraints [19,20].

2.5 SWIPT and NOMA

Since most devices run on batteries and use a lot of energy when sending and receiving information, and relay, EE is one of the crucial concerns being considered in 5G communications. Longer operating times are necessary for these devices. Periodic battery replacement is one potential solution to the energy shortage, but this will be very time-consuming, expensive to operate, and inconvenient, which will offset the advantages of employing wireless nodes. Consequently, various strategies are used in wireless networks to decrease the usage of energy and lengthen the life of the devices by, for example, creating energy-conscious algorithms, changing the duty cycle ratio of the devices, event-based communication, sending compressed data [21], or harvest energy from the sun or the wind [22].

The conventional methods for extending a network's lifetime frequently cause delays, distort the original data, or depend on the environment and time of day, which reduces their effectiveness. An improved and more adaptable method for operating energy-limited equipment is Simultaneous Wireless Information and Power Transfer (SWIPT), a new technique that extracts energy from RF signals. Benefits of SWIPT include the ability to extend network lifetime, effective transmission since both power and information are transmitted at once, and the use of overlapping signals as possible energy harvesting sources. By fusing the idea of SWIPT and additional 5G technology, energy efficiency may be increased and wireless networks can remain sustainable.

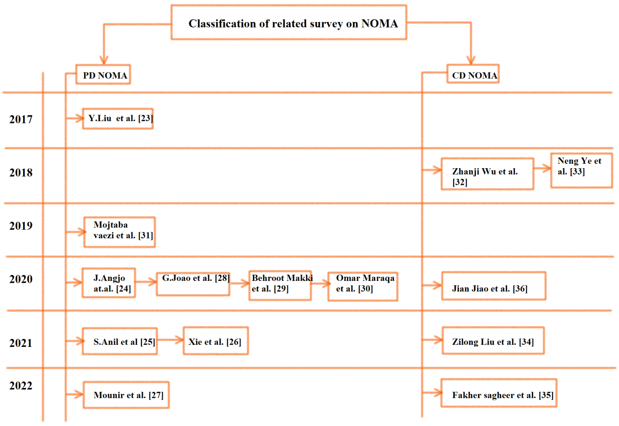


Fig. 2. Classification of relevant NOMA studies.

2.6 Contribution of this survey

We provide a thorough analysis of NOMA approaches in 5G in this research. We present a detailed analysis of current and future 5G technologies that support NOMA (HetNets, MIMO, massive MIMO, millimeter wave, CRs, and SWIPT), which differs from existing survey papers in that it focuses on how NOMA and this important technology interact with, benefit from, and influence the future of wireless network research. Additionally, new developments documented in recently published papers are included in this paper.

We also discussed several current difficulties and problems with NOMA implementation. Additionally, this article emphasizes how outdated current 5G standards are for attaining ultra-low latency. The main contribution of this study is listed below.

- ➢ The fundamental idea of NOMA, its requirements, and its benefits are examined.
- ➢ This paper discusses various related work and existing surveys.
- ➢ We comprehensively compare the existing NOMA literature based on channel estimation, the algorithm used, the wireless system, the coding technique, and the modulation scheme.
- ➢ Additionally, we investigate the ideas of PD-NOMA and CD-NOMA (Figure 2).
- ➢ Finally, we explain challenges and open issues. Besides this, we also spoke about possible strategies to deal with problems and unresolved difficulties (Figure 3).

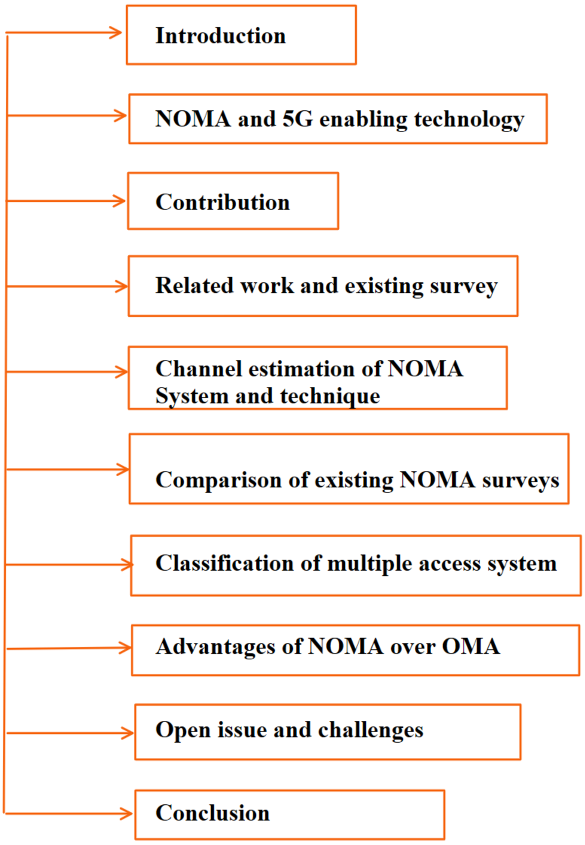


Fig. 3. Structure of this paper

3. Related Work

Currently, a list of literature is available that appears on the NOMA OFDM system model. In these papers typically the channel estimation of NOMA OFDM system criteria is reviewed and organized in Table 1 and Table 2.

The list of current surveys [37,39,41,43,44,48,49], that have appeared in the downlink transmission scenario. Similarly [38,40,46,52,54] explained the uplink transmission system. However [45,51,53], have discussed both downlink and uplink transmission techniques.

This paper investigated the parameters for performance evaluation such as average sum rate, SER, ergodic sum rate, BER, and MSE performance of the NOMA OFDM system. Interested readers can refer, for example, to the article released in [41,42,47], to explore the performance of average sum rate, ergodic sum rate [45], MSE performance [54], BER [37,39,40,44,46,48-50,52-54], and SER [43].

A. Hilario-Tacuri et al. [37], have discussed NOMA-OFDM system analysis on BER when there are memory-equipped high power amplifiers. To determine that system's BER, new theoretical expressions are established. About a NOMA-OFDM two-user downlink system, precise BER descriptions are provided and validated by the outcomes of a Monte Carlo simulation.

M. B. Balogun et al. [38], explained an effective WLS-based iterative algorithm created for NOMA-OFDM systems' channel estimation. The channel estimate is computed using an iterative (LMMSE) technique, with the WLS approach as a starting point. Multipath channels that are slow fading, as well as fast fading, are used to examine how well the iterative channel estimation algorithm performs. In MIMO OFDM NOMA systems, this method uses imperfect successive interference cancellation (SIC) to estimate the channel.

A. Nayak et al.[39] uses Variable Forgetting Factor based Recursive Least Square (RLS) algorithm to analyze the impact of channel estimation on BER performance for a downlink two user NOMA system.

S. Pandya et al. [40] examines a multiple-user NOMA receiver using deep neural network while taking channel estimation error into account. When using the NOMA system, the decoding of the symbol is done sequentially, and the success of the decoding is dependent on the ability to identify the prior user. The effectiveness of the deep neural network is also examined for different SNR values, and the BER is determined on a per-subcarrier basis using the LSTM algorithm.

A. Tusha et al. [41] have discussed a hybrid power domain NOMA scheme by the superposition of OFDM and index-modulated OFDM (OFDM-IM) technology. For achievable sum rate and BER, IM-NOMA performs better than conventional OFDM-NOMA.

S. Anil et al. [42] have proposed an iterative algorithm for channel estimation issues in an OFDM-based NOMA system. Hence, a single antenna is used by two users to transmit carrier data. The effectiveness of NOMA and NOMA-free channel estimation in MIMO OFDM technology is analyzed using the proposed iterative approach. NOMA, AOMA, and OMA average sum rate is simulated using an SNR variation rate of 5 dB.

Y. Xie et al. [43] developed a new receiver for the NOMA joint signal detector for the NOMA joint signal assisted by deep learning (DL). In an end-to-end manner, the DL-based receiver performs channel estimation, equalization, and demodulation simultaneously. Designing a time-series LSTM layer and integrating a CNN feature extractor to overcome the NOMA-OFDM challenge is the key contribution.

Z. Kabalci and M. Ali[44] confirm that by incorporating the OFDM waveform, we can demonstrate the NOMA systems' advantage over OMA schemes. Additionally, it is confirmed that the low-density parity check LDPC coding-based coded NOMA scheme outperforms the uncoded NOMA scheme about the BER performance parameter about transfer power. For the downlink scenario, the system's performance is evaluated in terms of throughput and PAPR.

In Y. Mao et al. [45] the ergodic sum rates of OFDM-NOMA uplink and downlink systems with RFO are determined and shown as integral forms under the assumptions of a receiver with perfect SIC. Additionally, the loss ratio is used to assess how RFO affects ergodic sum rate performance. It can also be used as a guide for RFO avoidance to keep ergodic sum rate loss within a given range.

H. S. Ghazi and K. W. Wesołowski [46], propose a better detection method, as opposed to conventional successive cancellation, that enables NOMA transmission in a significantly lower range of power variations among the terminals sharing radio resources in the uplink.

Table 1. Literature review

#	year	System model	Transmission scenario	Methods	Main finding
[37]	2021	One BS + two user	Downlink	HPA with memory	With a proper HPA scheme, NOMA-OFDM achieves a good BER rate
[38]	2019	One BS + two user	Uplink	Iterative LMMSE using WLS estimator	Explains the channel estimation issue. By using the iterative technique increased effectiveness, and general system performance.
[39]	2021	One BS + two user	Downlink	Variable Forgetting Factor RLS	BER performance
[40]	2022	One BS + two user	Uplink	LSTM algorithm, least square, and MMSE methods	With deep neural networks investigate SNR and BER analysis
[41]	2020	One BS + two user	Downlink	Log-likelihood ratio (LLR), ML detector	Average Bit Error Probability Analysis is presented, and the sum rate
[42]	2021	One BS + two user	NA	Iterative algorithm	Average sum rate of OMA, AOMA as well as NOMA, SNR analysis
[43]	2021	One BS + two user	Downlink	MMSE, LSTM, CNN	Complexity analysis compared to the proposed DL-based method and traditional methods. SER performance with SNR
[44]	2019	One BS + multiple user	Downlink	LDPC coding scheme	Downlink PAPR performance, BER performance comparison for coded and uncoded NOMA, throughput results
[45]	2019	One BS + two user	Downlink And uplink	RFO	Ergodic sum rate loss ratio
[46]	2019	One BS + two user	uplink	SIC detection algorithm	System performance in terms of BER vs SNR

[47]	2020	One BS + multiple user	NA	Resource allocation scheme	Sum rate, transmission power
[48]	2020	One BS + two user	Downlink	ML detector	BER performance of CIM-OFDM-NOMA, C-NOMA, uncoded C-NOMA, and IM-NOMA
[49]	2018	One BS + two user	Downlink	SEE-OFDM and NOMA techniques	BER performance for the SEE-OFDM VLC network, transmission power, data rate
[50]	2020	One BS + two user	NA	Iterative Bussgang receiver	PSD, SDR, and BER performance of the NOMA OFDM system
[51]	2010	NA	Downlink And uplink	LMMSE channel estimation, PDP modeling,	Channel estimation performance in terms of NMSE with respect to channel power gain
[52]	2021	One BS + multiple user	Uplink	DNN training model, channel estimators are LS and MMSE	BER performance with respect to SNR and detection performance
[53]	2017	One BS + multiple user	Downlink And uplink	MMSE-OSIC algorithm, channel estimators are LS and SOBI	BER performance of FD-MU-MIMO IDMA
[54]	2019	One BS + two user	Uplink	Iterative WLS algorithm	BER performance of the NOMA OFDM in the presence of CFO, MSE performance

3.1 Channel estimation of the NOMA system

The known channel attributes of a wireless communication link are provided via Channel State Information (CSI). At the receiver, the CSI should be calculated and typically transmitted back to the transmitter. As a result, the CSI of the transmitter and receiver may differ. The CSI could be statistical or real-time. Knowing the impulse response of the sent sequence allows one to view the instantaneous CSI's knowledge of the current channel circumstances. However, statistical CSI includes statistical features like fading distribution, channel gain, spatial correlation, and so on. The rate at which the channel conditions change effectively sets a limit for the CSI acquisition. Statistical CSI is acceptable in fast-fading systems when channel conditions vary over a longer interval than the symbol time. However, instantaneous CSI can be roughly calculated in slow-fading systems. Therefore, a channel estimation technique is incorporated into the signal's received accuracy. Intersymbol interference (ISI) in the received signal is due to the radio channel in mobile communications systems, which are often multipath fading channels. Several detection algorithms are utilized at the receiver side to eliminate ISI from the signal. These detectors should recognize the channel impulse response (CIR), which a separate channel estimator can supply.

3.2 Classification of channel estimation technique

The channel estimation approach is introduced to increase the accuracy of the received signal. Due to multi-path propagation, which causes ISI to mix with the signal received, radio stations in mobile communication networks are frequently the oldest or most fading channels. Numerous acquisition algorithm methods or detection algorithms are employed along with the receiver to eliminate the ISI from the signal. CIR's previous knowledge, which can be obtained by a different channel estimator, should be known to these detectors or acquisition procedures. Depending on an established sequence of various bits from distinct and repeated transmissions made during the transmitting burst, the channel estimation is made. This makes it possible for the channel estimator to estimate CIR using the signal's corresponding received samples and known broadcast bits for each burst individually. Figure 4 displays the channel estimation classification or category. These three types of estimations include training-based, blind, and semi-blind.

Besides the data symbol, the training-based estimations are carried out by placing the pilots in either a block- or comb-like configuration. Arranging pilots in blocks, a single symbol including many pilot subcarriers is periodically sent in a synchronous format by being time-aligned. For channels that are slowly fading, this kind of assessment is used. Pilots with periodic frequency bins are inserted into OFDM signals in a comb-type structure of pilot estimation.

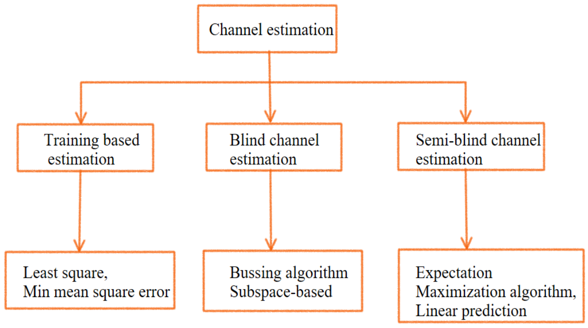


Fig. 4. Classification of the channel estimation

1) Training-Based Channel Estimation

Either block-type pilots or comb-type pilots can do this. Pilot tones are introduced into each frequency bin within the periodic intervals of OFDM blocks in block-type pilot estimation. This estimation works well for channels that slowly fade. Nevertheless, in comb-type pilot estimation, pilot tones with a particular period of frequency bins are injected into each OFDM signal[82].

2) Blind Channel Estimation

It is done by assessing the channel's statistical data and the unique characteristics of the delivered signals. Only channels with slowly fluctuating times are appropriate for this blind channel estimation, which has no overhead loss. However, training symbols or pilots familiar to the receiver are multiplexed with the data stream for channel estimation in training-based channel estimation[81].

3) Semi-Blind Channel Estimation

The semi-blind channel estimation algorithm uses pilot carriers and other natural restrictions to achieve channel estimation and is a blend of blind channel estimation and training-based channel estimation[81].

Table 2. Performance Comparison in existing NOMA papers

S.no	Year	Author	Performance analysis				
			Channel Estimation	Algorithm	Wireless system	Modulation	Coding technique
1	2019	Muyiwa B.Balogun et al. [38]	Yes	LMMSE, WLS	NOMA-OFDM	No	No
2	2020	A. Nayak et al.[39]	Yes	Variable Forgetting Factor RLS	NOMA-OFDM	16-QAM	No
3	2022	Pandya et al. S[40]	Yes	LSTM	NOMA-OFDM	No	No
4	2020	A. Tusha et al.[41]	No	LLR	OFDM-IM	BPSK	No
5	2021	Anil S. et al.[42]	Yes	Iterative algorithm	MIMO OFDM NOMA	No	No
6	2021	Y. Xie et al.[43]	Yes	DL-based	NOMA-OFDM	QPSK, OFDM	No
7	2019	Y. Kabalcı et al.[44]	No	No	NOMA-OFDM	OFDM	LDPC
8	2019	Y. Mao et al.[45]	Yes	No	NOMA-OFDM	No	No
9	2019	H. S. Ghazi et al.[46]	Yes	detection algorithm	NOMA-OFDM	16-QAM or QPSK	PLN
10	2020	X. Chen et al.[48]	Yes	No	NOMA-OFDM	index modulation	No
11	2018	G. Nauryzbayev et al.[49]	No	No	SEE-OFDM	QPSK	No
12	2020	J. Guerreiro et al.[50]	Yes	No	NOMA-OFDM	AM	No
13	2010	K.-C. Hung et al.[51]	Yes	No	OFDM	No	No
14	2017	N. Smaili et al.[53]	Yes	SOBI	NOMA-OFDM, MIMO	No	No
15	2019	M. B. Balogun et al.[54]	Yes	WLS	NOMA-OFDM	No	No
16	2021	Guangfu Wu et al.[76]	No	FSP	NOMA	No	No
17	2020	B. Makki et al.[77]	Yes	No	NOMA	QAM, QPSK	Channel coding
18	2020	A. Tusha et al.[78]	No	No	NOMA-OFDM, OFDM-IM	BPSK	No
19	2018	Y. Du et al [79]	Yes	SP, BSASP	NOMA	QPSK	No
20	2022	Sarkar, M. et al.[80]	Yes	$L2$-norm ELM	NOMA	No	No
21	2023	Alayu, M. et al.[83]	Yes	Arctangent LMS	NOMA-OFDM	No	No

4. Classification of Multiple Access systems

Multiple customers are served wireless or wired channels utilizing multiple access mechanisms. Conversely, communications channels whether they fall under the umbrella of wireless spectrum segment or cable connection tend to be sumptuous and costly.

Service providers must therefore distribute customers over constrained resources to earn a profit while efficiently using the available bandwidth.

The access techniques can occasionally permit the distribution of these constrained channels between numerous users to supply the economies of scale required for a profitable communication industry.

As seen in Figure 5, there are several types of multiple access, and OMA is split into FDMA, TDMA, CDMA, and OFDMA. NOMA is classified into PD-NOMA, CD-NOMA, PDMA, LPMA, BOMA, and SDMA. This paper mainly concentrates on NOMA.

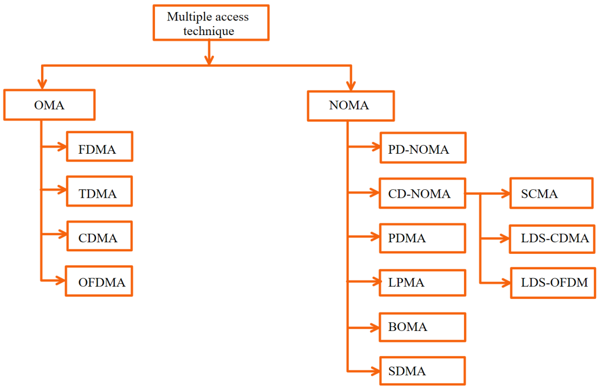


Fig. 5. Classifications of Multiple Access Systems

4.1. Power domain NOMA (PD-NOMA)

Future mobile communication systems may use a multiple-access method known as PD-NOMA that employs a capable receiver. By giving each user a variable amount of power, PD-NOMA serves several users simultaneously on the same sub-channel. This method is mostly used in 5G to enhance the SE and EE, and decrease latency.

Various transmission power coefficients are allotted to numerous users in the PD-NOMA system that have access to the same time-frequency resources. An iterative water-filling strategy to enhance the cumulative rate under total transmission power conditions was proposed in [55]. Although it was a rough optimal power allocation technique, the system application was unfeasible due to the algorithm's extraordinarily high computational complexity and the requirement for feedback information about the determined assigned power to each user. The fixed and fractional power allocation techniques were employed to deal with the computational complexity issue at a significant cost to overall system throughput.

4.2. Code domain NOMA (CD-NOMA)

The other multiplexing domain, known as code domain NOMA, can be based on signature codes. By allocating different signature codes to various users, this approach can handle huge customer transmissions inside the same time/frequency resource block. Code domain NOMA has the intriguing property of performing better in power-balanced settings when all signature sequences are unique. The detection techniques utilized in CD-NOMA, such as the MPA, ML, and maximum posterior MAP detection, are sophisticated and nonlinear. As a result, compared to PD-NOMA, CD-NOMA has attracted less research attention. There are other CD-NOMA schemes, such as IDMA, SCMA, LDS-CDMA, and LDS-OFDM, IDMA.

In the CD-NOMA approach, the signals are multiplexed at the transmitter side using user-specific spreading sequences. Some primary benefits of this method are low density, low intercorrelation, and support for free access. A more modern variation of CDMA called CD-NOMA was introduced in the nineties. Regarding CDMA, CD-NOMA receivers must determine which of the receivers' active codes are present and approximate actual data. The core components of CD-NOMA are CS, Gaussian random, and sparse code.

5. Advantages of NOMA over OMA

High SE: NOMA offers higher SE since more users can access the service through each RB. OMA only allows one RB to each user, wasting bandwidth[56]. NOMA can easily be coupled with other 5G technologies, such as HetNets, mmWave, mMIMO, CR, and D2D, to boost the network's throughput.

Massive connectivity: Non-orthogonal properties of NOMA enable it to host billions of smart devices. Due to the lower size and irregular structure of the packets, it is appropriate for both the IoT [57] and the Tactile Internet [58]. While in OMA one device purchases one RB, RBs are wasted, in NOMA, a single RB is used by several devices to access the services.

Ultra Low Latency: Due to the (Het-Net) design used in 5G, the standards for latency are stricter. Due to OMA approaches relying on access-grant requests, which increase signaling overhead and transmission lag, they don't fit the bill for this type of architecture. When data is transferred using LTE, the access grant request process takes 15.5ms [59]. NOMA, which provides grant-free distribution, is utilized to solve the problem, particularly in the UL situation. Additionally, NOMA offers flexibility across A substantial amount of devices by application requirements and device QoS.

Fairness: Because NOMA ensures user equality, more power is distributed to the weak user and less to the strong user. Then, QoS in terms of throughput is assured for both strong and weak users. The authors in [60] offer fair power distribution techniques to improve fairness between various users. CoMP and cooperative communication are also essential for improving the fairness of the QoS of weak consumers [61], [62]. Moreover, the power allocation strategy suggested in [63] assumes average CSI at the transmitter to enhance user fairness.

Details of SC and SIC are provided since they are two fundamental methods for understanding the NOMA system.

Superposition Coding (SC): SC is a technique that can simultaneously send data from one source to many receivers, and it was first introduced in [64]. Or, it enables the transmitter to send data from several users immediately. Superposed communication includes sending a signal for television to numerous receivers and delivering a speech to a group of people from different abilities and backgrounds.

Successive Interference Cancellation (SIC): Covers initially introduced the SIC method for each receiver to decode the superposed information [64]. By utilizing parameters on the fluctuation in signal strength between the signal of interest, SIC is theoretically allowed. The basic tenet of SIC is the continuous decoding of the user's signal. The signals from the preceding user are first removed from the combined signal before the signal from the following user is decoded. If SIC is active, the first user signal is always decoded, while the second is always treated as interference.

Furthermore, the benefit of the interference from the earlier signal has been removed allowing for the subsequent decoding of the latter user signal. Prior to SIC, users were placed in groups based on how powerful their signals were. In this arrangement, the receiver could decode the stronger signal first, take it out of the combined signal, and then separate the weaker signal from the others. Remember that every user uses the interference of other users, such as signal-receiving noises, to decode.

Capacity representation of NOMA

The following is an expression for NOMA's Shannon capacity:

$$C_p^{NOMA} = log_2\left(1 + \frac{a_p\rho|h_p|^2}{1+a_p\rho|h_p|^2}\right) \tag{1}$$

$$C_q^{NOMA} = log_2\left(1 + a_q\rho\left|h_q\right|^2\right) \tag{2}$$

Where, ρ is the transmit SNR at the BS, h_p and h_q are the channel gains, while a_p and a_q are the power allocation coefficients that fulfill $a_p + a_q \leq 1$

When SNR increases, i.e, $\rho \longrightarrow \infty$ then

$$C_{sum,\infty}^{NOMA} \approx log_2\left(\rho\sqrt{\left|h_p\right|^2\left|h_q\right|^2}\right) \tag{3}$$

$$C_{sum,\infty}^{NOMA} = log_2\left(\rho\left|h_q\right|^2\right) \tag{4}$$

MIMO-NOMA

The following is the MIMO-NOMA mth cluster's capacity:

$$C_{m,L}^{NOMA} = \sum_{l=1}^{L} log_2\left(1\frac{\rho\Omega_{m,l}\left|v_{(m,l)}^H H_{(m,l)} P_m\right|^2}{1+\rho\sum_{k=1}^{L}\Omega_{(m,k)}\left|v_{(m,k)}^H H_{(m,k)} P_m\right|^2}\right) \tag{5}$$

where $\rho = \frac{1}{\sigma_n^2}$, σ_n^2 is the noise variance.

To boost the capacity for any power split in MIMO-OMA, the same power split can be used in MIMO-NOMA. MIMO-NOMA can operate at higher capacities, particularly when the power split is best for MIMO-OMA.

6. Basic of NOMA

The illustration of downlink and uplink NOMA is illustrated in Figure 6 and described below:

1) Downlink NOMA

In DL situations, the SC mechanism is used to multiplex the signals at the transmitter side (the BS). Various power allocation coefficients apply to these signals. The SIC approach is employed on the receiver end to distinguish interfering signals. Power allocation coefficients are distributed based on the consumers' channel conditions. User with bad channel conditions is given high power, while users with superior channel conditions are given low power.

In DL OFDM-NOMA, the signal delivered by the BS on sub-carrier k, X_k, and the signal obtained by the user m on sub-carrier k, $R_{m,k}$, are each represented in the frequency domain in the following ways, respectively;

$$X_m = \sum_{m=1}^{M} \sqrt{\alpha_{m\,,\,k}\, p_k}\, A_{m,k} \quad \frac{1 \le m \le M}{0 \le k \le K-1} \tag{6}$$

$$R_{m,k} = H_{m,k}\left(\sqrt{\alpha_{m,\,k}\, p_k}\, A_{m\,,\,k}\right) + N_{m,k} \quad \frac{1 \le m \le M}{0 \le k \le K-1} \tag{7}$$

where K represents all of the sub-carrier in OFDM symbols, The power allocation ratio for user m on subcarrier k is $\alpha_{m,k}$, $A_{m,k}$ is the user m data superposed on the sub-carrier k, $H_{m,k}$ is the frequency response of the channel between the BS and $N_{m,k}$ is the frequency domain, and user m is on sub-carrier k.

2) Uplink NOMA

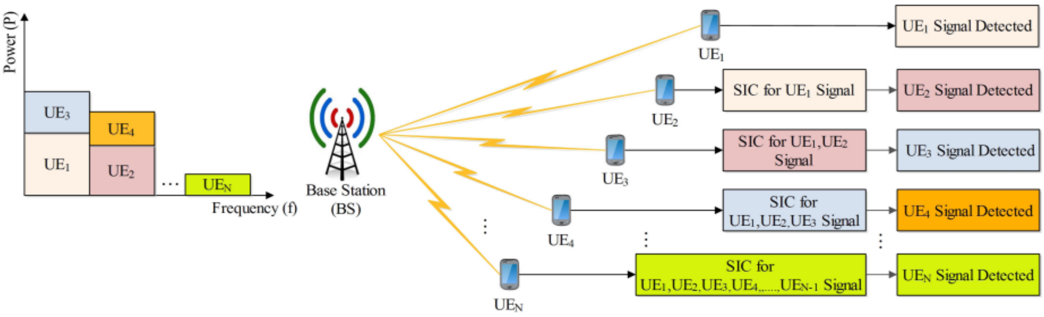
Every UE transmits its signal to the BS in an uplink situation. Then, using the SIC approach at the BS, the signals from the UEs are divided according to their unique power allocation coefficients. The user's maximum battery power determines how much strength may be delivered per user. In contrast to downlink NOMA, each user may individually use their battery power to the fullest extent provided that their channel gains are adequately diverse.

However, the user-transmitted signal on subcarrier k, $X_{m,k}$, and the BS received signal on subcarrier k, R_k, are each represented in the frequency domain in UL OFDM-NOMA by;

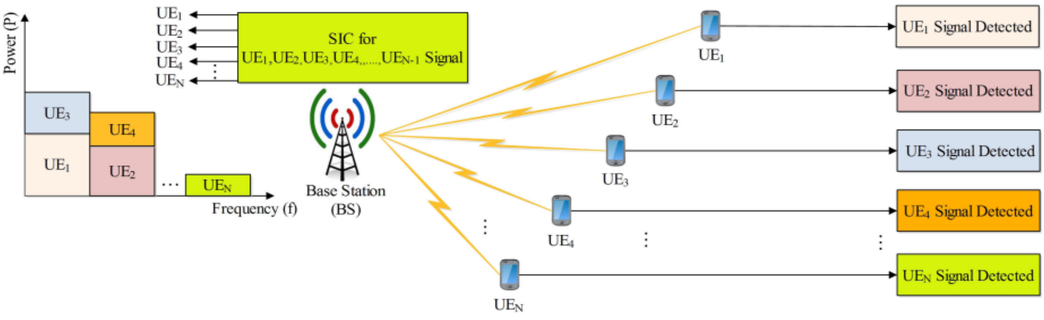
$$X_{m,k} = \sqrt{\alpha_{m,\,k}\, pk}\, A_{m,k} \quad \frac{1 \le m \le M}{0 \le k \le K-1} \tag{8}$$

$$R_k = \left(\sum_{m=1}^{M} H_{m,\,k} \sqrt{\alpha_{m,\,k}\, p_k}\;\; A_{m,\,k}\right) + N_k \quad \frac{1 \le m \le M}{0 \le k \le K-1} \tag{9}$$

where Nk is AWGN's illustration in the frequency domain on sub-carrier k at the BS.



(a) Downlink NOMA



(b) Uplink NOMA

Fig. 6. Downlink and uplink NOMA.

In Ref. [65], to set the amount of power allotted, the program first arranged scheduled users based on their channel gains in declining order, and then it applied a recursive process containing a recursion factor. The decay and fixed-value recursive factor cannot be adapted to different conditions and must be established beforehand. The parameter α_{fix} was employed to control user fairness and system efficiency under the total power constraint. The systems may distribute additional power to numerous users in an environment with good channels as α_{fix} rises. The following could be used to express the multi-user power allocation coefficients:

$$\begin{cases} \beta_b\,(n) = \alpha_{fix}\beta_b(n+1) \\ \quad \sum_{n=1}^{N} \beta_b(n) = 1 \end{cases} \tag{10}$$

$$\beta_b(n) = \frac{1}{\sum_{k\in S}\left(\frac{g_b(k)}{n_b(k)}\right)^{-\alpha_{ftpc}}} \left(\frac{g_b(n)}{n_b(n)}\right)^{-\alpha_{ftpc}} \tag{11}$$

In Ref. [66], for the allocation of fractional power on a wireless channel, an algorithm has been used to account for shadow effects and route loss. By altering the decay factor α_{ftpc}, different users may obtain different powers under various channel settings. Equal power distribution might be accomplished when $\alpha_{ftpc} = 0$. More power was given to the number of users with poorer channel gains as α_{ftpc} rose.

7. Open issues and challenges

1) Imperfect CSI

It's been noted that many researchers with multi-user detection and CSI for the best resource allocation have already worked extensively on NOMA. However, because of feedback and channel estimate flaws, perfect CSI is not feasible. It's been noticed that interference occurs when users' CSI is unknown. This takes place as a result of the fact that incomplete CSI leaves some signals from those other users' signals behind. To eliminate the conflicting signal from the BS, perfect joint precoders are needed, and sophisticated channel estimate techniques are used to obtain more precise channel information to handle the model with faulty CSI. Given the description above, it is still an issue that needs to be resolved to lessen the impact of errors. [67], [68].

2) Security
Security is a crucial concern that must be addressed in every generation of technology for wireless communications. It is essential to pay close attention to the wireless channel's signal broadcast because it can be intercepted. The author of [69] presented a convincing theory for improving wireless channel security using cryptographic methods at the physical layer. The authors of [70] proposed a method to enhance the network's secrecy in contrast to [69]. Additionally, it increases the channels' capacity for eavesdropper channels, however, with a generational shift, new strategies are needed to enhance physical layer security [71].

3) Hardware complexity
The upgrading of NOMA with a SIC detector complicates hardware by separating the signals with increased power levels from those with lower levels to collect user data. When many users or a fast signal transmission is required, the detection delay has been shown to increase, which may affect the UEs' batteries. Therefore, to deploy NOMA in ultra-dense networks, UEs would need enough battery capacity, which is impossible. Fair power distribution and efficient user cluster strategies are required to solve it.

4) Resource allocation
By distributing radio resources across users, it improves data rates, capacity, and user equality. As the number of users increases in a multi-cell scenario, resource allocation to users becomes more difficult due to the limited radio resources in the spectrum. NOMA has made good use of its resources because of its ability to serve several customers simultaneously at different power levels. However, distributing resources to the user via the NOMA system is very complex due to cross- and co-channel interference [72]. To minimize that interference, a suitable resource allocation plan is necessary, which minimizes the effects of error spread.

5) Receiver design
Users' performance suffers due to the complexity, SIC receiver used, and error propagation. Hence, a more precise efficient nonlinear detection algorithm is needed to solve this problem, lowering the impact of errors. The Gaussian distribution approximation method, the MPA-based receiver effectively avoids the problem of error transmission despite its enormous complexity. Increased connectivity leads to more accurate and superior results. Furthermore, it was discovered that Data symbols are decoded and detected by MPA synchronously, particularly for networks with nodes for variables and observations. To enhance signal identification performance, the receivers are also more efficient at decoding, demodulating, and exchanging data signals. However, to leverage problems like precise signal identification, error propagation, and effective receiver design, performance on the receiving end must be improved. [73–75].

6) Propagation of errors during SIC implementation
To determine the data rate whenever SIC is performed at the receiver's end, a user with good channel circumstances removes the signal of a user with a weaker channel condition. But in practical situations, the NOMA technology can't determine the channel with enough accuracy, therefore the receivers are affected by the SIC detection. Hardware complexity, TO, and CFO-related problems are to blame for this. Hence, error propagation and inaccurate detection frequently happen during the SIC process. An enhancement in the estimation quality of the indicated hardware limitations is required to fix the above problem and improve QoS [84-85].

8. Conclusion

Nowadays NOMA become a well-known transmission technique for a wirelessly connected device. High system throughput, low latency, and widespread connectivity are just a few of the essential performance requirements for 5G and it is a crucial enabling technology. In this article, the integration of NOMA with the primary candidate communications schemes and technologies for high-rate data transmission is thoroughly reviewed in the literature with future wireless networks including HetNets, SWIPT, MIMO-NOMA, Massive MIMO, mmWave, cognitive radio, and other enabling technologies. Studies already conducted have unequivocally shown that NOMA can increase system throughput. Readers will hopefully gain a better understanding of the benefits and opportunities that NOMA provides and its practical application scenarios. NOMA will be a crucial component of 5G, LTE-A, and digital TV networks, as shown by recent industrial efforts to include NOMA in these standards.

This survey consists of four sections. The survey's first section covered the introduction, history, and NOMA standards. The second part of the paper discussed the related work and existing survey. Comparison analysis of the current NOMA-OFDM survey is conducted based on sum rate, bit error rate (BER), spectral efficiency (SE) as well as estimation error (EE). Lastly, open issues and difficulties of NOMA have been discussed.

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List of abbreviation

Abbreviation	**Description**
5G	Fifth-Generation
AM	Amplitude Modulation
AOMA	Adaptive Orthogonal Multiple Access
AR	Augmented Reality
BSASB	Block Sparsity Adaptive Subspace Pursuit
CD-NOMA	Code-domain NOMA
CFO	Carrier Frequency Offset
CNN	Convolutional Neural Network
CR	Cognitive Radio
CS	Compressive Sensing
DNN	Deep Neural Network
EE	Estimation Error
FD	Full Duplex
FSP	Full Search Power
Het-Net	Heterogeneous Network
HPA	High Power Amplifier
IDMA	Interleave Division Multiple Access
LDPC	Low-Density Parity Check
LDS-CDMA	Low-Density Spreading CDMA
LLR	Log Likelihood Ratio
LMMSE	Linear Minimum Mean Square-Error
LS	Least Square
LSTM	Long Short-Term Memory
LTE	Long Term Evolution
MA	Multiple Access
MIMO	Multiple Input Multiple Output
ML	Maximum Likelihood
MMSE	Minimum Mean Square Error
NMSE	Normalized Mean Square Error
NOMA	Non-Orthogonal Multiple Access
OFDM	Orthogonal Frequency Division Multiplexing
OMA	Orthogonal Multiple Access
OSIC	Ordered Successive Interference Canceler
PAPR	Peak-to-Average Power Ratio
PD-NOMA	Power-Domain NOMA
PDP	Power–Delay Profile
PLN	Physical Layer Network
PSD	Power Spectral Density
QoE	Quality of Experience
QoS	Quality of Service
RB	Resource Block
RFO	Residual Frequency Offset
RLS	Recursive Least Square
SB	Subspace Pursuit
SC	Superposition Coding
SCMA	Sparse Code Multiple Access
SDR	Signal-to-Distortion Ratio
SEE	Spectral and Energy-Efficient
SER	Symbol Error Rate
SIC	Successive Interference Cancellation
SOBI	Blind Source Separation Approach
SWIPT	Simultaneous Wireless Information and Power Transfer
TO	Timing Offset
UE	User Equipment
VR	Virtual Reality
WLS	Weighted Least Square