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SYSTEMATIC ANALYSIS AND STRATEGIC REVIEW OF MIMO-NOMA SYSTEMS

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ABSTRACT

One of the effective technologies dealing with the transmission that occurs at the overloaded condition with limited resource and improved spectral efficiency is Non-Orthogonal Multiple Access (NOMA). Multiple-Input Multiple-Output (MIMO) is used for fulfilling the demands of 5G communication systems. Integration of both MIMO and NOMA approaches is also explained in the previous researches for improving the communication. The purpose of NOMA is for utilizing multiple accesses into power domain for providing channel assignment and power allocation. Thus, optimal power allocation is an important parameter in 5G communication so as to utilize the NOMA systems effectively. Accordingly, this survey presents different techniques in MIMO-NOMA systems. Thus, this review article provides the detailed review of research papers presenting various MIMO-NOMA methodologies. The papers reviewed are classified into following types, namely Pilot based techniques, Pre-coder based techniques, Beam forming based techniques, Sum rate based techniques and Cluster-based techniques. Moreover, an elaborative study and discussion are made by concerning fading channels, antennas utilized, implementation tools and evaluation parameters obtained by various techniques. Eventually, the research gaps and issues of various MIMO-NOMA classification schemes are presented for extending the researchers towards a better contribution of significant MIMO-NOMA systems.

Keywords: MIMO-NOMA, power allocation, sum-rate, energy efficiency, fading channels.

1. INTRODUCTION

Enhancing both spectral and energy efficiencies in MIMO systems [1,2] have been paid much interest by a lot of researchers in academic and industrial areas [3]. The channel capacity of wireless communication in the MIMO system [4] can be improved, without using any additional power and bandwidth [5]. Due to its better spectral efficiency, NOMA [6,7] has been considered as an effective approach for the fifth generation (5G) [8] mobile networks [9,10]. The NOMA users residing in a single cell are distributed by a base station in a specific frequency or time channel, and their signals are combined by various coefficients of power allocation [10]. Particularly, NOMA [11,12] is a multiuser multiplexing approach for providing multiple access in the power domain [13]. Due to improper channels in MIMO-NOMA [14], the design of MIMO-NOMA [15] is a complex similar to Single-Input-Single-Output (SISO) networks, and thus, it is complicated for users in terms of the channel matrix [16]. In spite of using NOMA [17] for the systems based on SISO nodes, the inclusion of MIMO nodes can enhance the spectral efficiency [18].

The interest of researchers in the recent years presents attention in the field of MIMO and NOMO, which is also termed as MIMO-NOMA. Incorporation of NOMA and MIMO technology exhibit significant potential for enhancing the system performance regarding power efficiency, spectrum reuse probability, and throughput efficiency [19]. In MIMO-NOMA systems, the users are clustered with the users belongs to the similar cluster to minimize the complexity of Successive Interference Cancellation (SIC) in the NOMA systems, making use of a shared beam former [20].

In downlink multiuser MIMO [21], every User Equipment (UE) is used for serving more than one beam using number of transmitting Base Station (BS) antenna and number of receiving antennas. The inter-beam interferences are removed completely when the antennas present in the transmitter side is equal to or higher than the antennas available at the receiving side [22]. Compared to the downlink MIMO-NOMA systems [23], uplink MIMO-NOMA exhibits huge difference in the policy of transmitting power allocation and the order of SIC operations [24]. To obtain improved spectral efficiency under various scenarios, the MIMO and the NOMA technologies are combined to form a promising result [25] and offers an essential degree of freedom [26,27]. One of the interesting topics for conventional and small cell network is power allocation [28].The power allocation design is considered as an important element for certain significant applications, including the radars with low-cost and small-capacity batteries that are often irreplaceable and non-rechargeable. Moreover, management of power allocation model plays a vital role in the hostile military operational environment, wherein the radar network attains a low probability of interception [29]. Power allocation [30] is the method for transmitting total available power that arrives from various antennas. A dynamic power allocation approach is developed for assigning the optimized power for various users for achieving improved sum rate. Also, iterative optimization techniques were introduced for power allocation [29,31]. Moreover, the power allocations among the users are performed via downlink transmissions in open-loop MIMO [32].

The primary intention of this paper is to provide a detailed study of the various MIMO-NOMA methods.

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This review deliberates the existing MIMO-NOMA methods employed in the distinct research works for various applications. The survey is made by considering different fading channels, number of antennas utilized, metrics and tools used for the implementation. Moreover, the existing approaches have been surveyed by categorizing them as pilot-based techniques, Beam-forming based techniques, Sum rate based techniques, Cluster-based techniques and pre-coder based techniques. Then, the survey is performed for the exploitation of the research gap and issues. Thus, it acts as the motivation for the future extension of MIMO-NOMA applications.

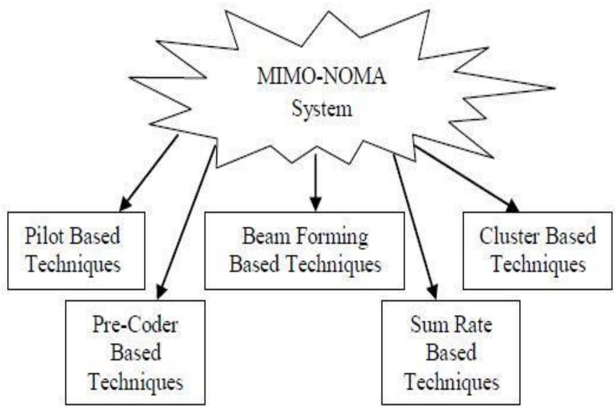

Figure-1. Classification of MIMO-NOMA systems.

This article is organized as: Section 1 provides the brief introduction about the paper, Section 2 gives the literature review of the existing MIMO-NOMA classification approaches and Section 3 elaborates analysis and discussion of the survey. In section 4, the research gaps and the future works are discussed and the conclusion is made in Section 5.

2. LITERATURE SURVEY

This section extensively discusses the review of different MIMO-NOMA techniques. The categorization of distinct MIMO-NOMA systems is pictorized in Figure-1. The techniques of MIMO-NOMA is categorized into five, namely Pilot based techniques, Cluster-based techniques, Beamforming based techniques, Pre-coder based techniques, and Sum-rate based techniques. The review of MIMO-NOMA techniques provides a clear visualization of the suggested methods along with their significances and drawbacks.

2.1 Classification of mimo-noma techniques

The distinct research works adopting varying MIMO-NOMA schemes are elaborated in this section.

2.1.1 Pilot based techniques

The research papers employing the pilot based techniques in the MIMO-NOMA systems are discussed below, Hieu Trong Dao and Sunghwan Kim [3] investigate the problem for pilot power allocation in multi-cell multi-user MIMO networks to reduce the sum rate. It was based on an assumption that each user could utilize different pilot power rather than conventional massive MIMO systems [33], which use shared pilot power for every user in the network when the pilot power was fixed in every cell. The method demonstrates that the number of BS antennas exceeds limit, the user's signal-to-interference-and-noise ratio is based on the large-scale fading effect and pilot power of all the users, whose pilot sequence is similar. The popular Lagrange multiplier method was employed to resolve the optimization issue such that the uplink achievable rate was maximized. Moreover, two algorithms were developed based on original and extended optimization problems so that pilot power can be optimized. In [34], Zhiqiang Wei developed a Joint pilot and Payload power Allocation (JPA) approach of MIMO-NOMA uplink systems by SIC (MRC-SIC) receivers and Maximum Ratio Combining to avoid the error propagation issues. The Signal to- Interference-plus-Noise Ratio (ASINR) of user while the decoding of MRC-SIC is determined. In addition, the JPA approach is developed as a non-convex optimization issue for expanding the minimum weighted ASINR and is resolved using genetic programming.

Junjie Ma *et al.* [35] developed large antenna system of pilot transmission approach using NOMA. Pilot structures, such as Superimposed Pilot (SP) and Orthogonal Pilot (OP) are discussed. In SP, pilots occupy data, whereas, in OP, pilots involve time or frequency. Here, the authors had studied Iterative Data-Aided Channel Estimation (IDACE) receiver that used for decoding the data partially for the channel estimation. For OP and SP, the achievable rates attained by the systems that use IDACE receivers are determined. The method demonstrates the portion of pilot power seems to be zero for SP using a Gaussian signal. In statistical physics, the developed scheme had attained more reliable result compared to the replica method. However, due to the availability of multiple codes in the replica method, it is complex for executing. Finally, the method shows that the code optimization of OP is better than SP in improved mobility environment using a huge number of users.

Hei Victor Cheng *et al.* [36] examined the performance of NOMA in multiuser MIMO under various schemes in which the CSI was achieved via pilot signaling. The study based on the rate is performed using various pilot signaling schemes, which include downlink and uplink pilots. Also, the performance achieved by the NOMA scheme in comparison with the existing orthogonal access schemes based on orthogonal pilots. By selecting optimal parameters for the power allocation, the technique can be considered as orthogonal scheme.

Chongbin Xu *et al.* [37] presented an overview regarding massive MIMO, NOMA and Interleave Division Multiple Access (IDMA) in a single model. The method focused on the multi-user gain that allows multi-user transmission while dealing with massive MIMO, using a potential rate improves in the range of tens or hundreds. Under perfect CSI, both NOMA and Orthogonal Multiple Access (OMA) could attain better capacity. Without perfect CSI, neither NOMA nor OMA [38] can perform well. To overcome this difficulty, a solution depending on

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iterative Data-Aided Channel Estimation (DACE) and IDMA, was developed. This approach can achieve robust and high throughput based on pilot contamination issues. As MRC does not include matrix inversion, the receiver cost is low. Under Time Division Duplex (TDD), the acquired CSI are utilized for supporting Zero-Forcing (ZF) for the down-link solutions.

2.1.2 Pre-coder based techniques

The distinct research works employing the pre-coder based techniques for the MIMO-NOMA systems are presented below,

Zhiyong Chen and Xuchu Dai [39] designed Minimum Euclidean distance (MED) s of MIMO-NOMA downlink systems. Initially, the MED precoding algorithm for 2-user 2 2 MIMO-NOMA downlink are developed for integrating the methods of MED precoding for multicast and unicast MIMO networks. In addition, for expanding the MED precoders to general multi-user concepts, two algorithms, named orthogonality defect and condition number were developed, for user pairing.

Hong Wang *et al.* [24] addressed the usage of new transceiver approach and the NOMA for MIMO uplinks. A NOMA scenario depending on group interference cancelation was developed for minimizing the total power consumption depending on the rate of individual needs. In this scenario, equalizers and precoders for users belonging to the similar group are considered, and closed-form design procedures of user precoders are proposed.

Van-Dinh Nguyen et al. [5] had considered beam-formers/ pre-coders at the BSs of signal superposition in MIMO-NOMA multi-cellular network for enhancing the sum throughput, satisfying the needs of QoS users. Generally, such a design issue is complex as the objective function is the maximization of non-smooth and nonlinear function that focuses on the non-convex constraints. As a solution to this, numerous path-following algorithms were introduced, invoking a simple convex problem with reasonable dimension. Producing a sequence of enhanced points, the method could converge easily to a local optimum.

Yuhao Chi *et al.* [40] developed a simple Multi-User Detector (MUD) for detecting the signal for user depending on the interference, which is caused due to the superimposed signal from another user. Then, the authors had introduced simple task based on three conditions for designing the multiuser code, which copes with the varying number of users and antenna configurations. Accordingly, minimum rate Repetition-aided Irregular Repeat-Accumulate (Rep-IRA) codes are designed in MIMO–NOMA, to achieve low complexity and low rate. As the code designs depend on the analysis results of EXIT chart, a careful theoretical evaluation is required to improve the study further.

Di Zhang *et al.* [41] developed the non-regenerative massive-MIMO-NOMA network to improve the system Spectrum Efficiency (SE). Additionally, the MMSE-SIC decoding approach was utilized for decoding the information at the receiver side. With the aid of matrix theories, the sum rate and system capacity are addressed using closed-form expressions. The method shows the number of transmitting antennas, and user offer positive correlations, but affects the system capacity performance. By increasing the value of SNR, higher performance can be attained with maximum capacity. Moreover, comparison among massive MIMO-OMA system, the massive MIMO-NOMA approach is able of achieving improved performance, which increases through the increasing number of transmitter antenna.

2.1.3 Beamforming based techniques

The research papers utilizing the beam-forming based approaches for the MIMO-NOMA systems are elaborated as follows,

Bichai Wang *et al*. [42] developed an mmWave transmission based on energy efficient and spectrum approach for combining the concept of NOMA with beam space MIMO. The total number of users is made higher than the total RF chains at similar time-frequency resources while considering NOMA in beam space MIMO systems and the sum rate in a mmWave channel framework is maximized compared to the existing beamspace MIMO. To avoid the inter-beam interferences, a pre-coding approach is developed using Zero-Forcing (ZF) principle. At last, a dynamic power allocation algorithm is introduced to enhance the sum rate and an iterative optimization algorithm is established for power allocation.

Sunil Chinnadurai [43] investigates robust beam forming model for solving the EE maximization issues in massive MIMO-NOMA downlink system with imperfect CSI at the BS. Additionally, technique named Joint User Pairing and Dynamic Power Allocation (JUPDPA) is developed to reduce the inter-user interference and improve the communication among the users. The technique considers imperfect CSI by accumulating uncertainties for channel matrices using a model, like the Ellipsoidal Uncertainty Model (EUM). In order to tackle the above issue, the fractional nonlinear objective function was converted based on its parametric form. An effective iterative approach is proposed based on Concave-Convex Procedure (CCCP). At last, Dinkelbach's approach is utilized for determining maximum energy efficiency. In downlink MIMO-NOMA network, Maoxin Tian *et al.* [44] addressed a robust beamforming design depending on a cutting-set method with the deliberation of worst-case channel uncertainties. The developed cutting-set approach was comprised of various steps of pessimization and optimization. In the optimization phase, user in thr the worst-case achievable rate, who is in the constraints of worst-case achievable rate, was improved with respect to the subset of uncertainties in the channel, whereas in the pessimization process, the method determines worst-case channel uncertainties.

In [45], Shimei Liu and Chao Zhang examined the downlink multiuser beam-forming system with limited CSI feedback. Random and zero-forcing beam forming are the two existing beam-forming approaches that are studied in the multiuser NOMA downlink network. With the imperfect CSI, the authors had developed the user selection and PA techniques to minimize the interference among the NOMA users and for enhancing the sum-rate of NOMA system, respectively.

Ke Xiao *et al.* [25] proposed on opportunistic massive MIMO-NOMA approach depends on based on system of multicast service, for the 5G communications. The developed scheme superimposes the signal of NOMA users on the multicast signal, utilized SIC for separating the signal of NOMA users among the multicast signal. The null space-based interference cancellation is used for removing the leakage signal produced from last groups. Finally, multi-user MIMO (MU-MIMO) linear pre-coding is applied in the unicast signal.

Jingjing Cui *et al.* [46] examined the power minimization issues in downlink MIMO- NOMA systems with imperfect and perfect CSI. The authors have exploited the fixed-point update PA method on the basis of two kinds of CSI and thereby, developed a joint PA and beam forming approach. When perfect CSI is available both at the BS and the users, the expression of a closed form based on the receiving detection in each vector is solved. Moreover, an assumption is made that the CDI is named for BS and the users and power minimization problem are addressed. The optimal detection vectors at the receiver are produced using one-dimensional search technique and Semi-Definite Programming (SDP) relaxation for allocating power.

2.1.4 Sum rate based techniques

The research works adopting the sum rate optimization or maximization classifier in the MIMO-NOMA systems are discussed below,

Jin-ho Choi [32] examined the optimal power allocation for maximizing the total sum rate of MIMO-NOMA systems using layered transmissions. Performing the optimal power allocation based on CSI, a closed-form expression was derived for sum rate. The property based on scaling in MIMO-NOMA with transmitting layers is analytically shown with both upper-bounds and lower-bounds on the sum rate. From the upper and lower-bounds based on the sum rate, the scaling property is concluded.

Chen Chen [47] applied NOMA in MIMO-depends on multi-user Visible Light Communication (MIMO-VLC) networks to enhance the sum rate of MIMO. Here, Normalized Gain Difference Power Allocation (NGDPA) technique was introduced utilizing the channel conditions of the users for adaptive and effective power allocation in MIMO-NOMA-VLC networks with minimized computational complexity. The sum rate performance of an indoor 2×2 MIMO-NOMA based VLC system is examined via numerical simulations. In addition, sum rate of the 2×2 MIMO-VLC system can be greatly enhanced for employing NOMA with NGDPA method compared to NOMA based on GRPA.

Ziad Qais Al-Abbasi [48] analyzed resource allocation for a downlink multiuser MIMO-NOMA system, in which the users more than two are linked together and the remaining users are associated to the null space as interference. The group of users utilized NOMA along with a power allocation approach that has low complexity to maximize the sum rate. Additionally, an optimization issue is generated for maximizing the sum rate considering proportional fairness constraints and total power. A sub-optimal solution having reduced complexity is attained while considering a scenario with two users and is broadened to the multi-user scenario using hierarchical pairing approach.

Xiang Chen *et al.* [49] developed a scheduling technique, named User Pairing and pair Scheduling (UPaS), for choosing first and second user to every group to attain the outage performance and high sum rate in MIMO-NOMA. The technique, when employed in multi-antenna user systems, could attain improved performance related with conventional algorithms. For applying NOMA in massive MIMO systems, the method considers an Interference Cancellation Combining (ICC) matrix for removing the inter-pair interference to improve the receiving SINRs for the individual present in user pair.

Chen Chen *et al.* [50] had examined the Resource Allocation (RA) issues that can be mitigated using beam forming (BF) and User Selection (US) techniques adopted in downlink MIMO-NOMA system. Here, the authors designed the Multiple-User CSI depends Singular Value Decomposition (MU-CSI-SVD) BF scheme together with the minimization of power US approach. Comparing the conventional US approaches with the Min-power approach, it had attained higher sum rate in perfect CSI environment with less computational. Therefore, RA scenario for 5G MIMO-NOMA systems was introduced for enhancing the performance with less complexity in computation in both CSI environments.

Ming Zeng *et al.* [51] had integrated the performance of sum rate in MIMO-OMA and MIMO-NOMA. The result shows that MIMO-NOMA is better than MIMO-OMA regarding ergodic sum rate and sum rate for a simple schemes of two users. Moreover, for a several practical scenario of numerous users, with two users paired into a cluster and dividing a common beamforming transmitting vector, MIMO-NOMA has shown superior performance than MIMO-OMA system.

Zhiguo Ding *et al.* [52] proposed a MIMO-NOMA signal alignment framework for applying both downlink and uplink transmissions. Applying stochastic geometry, the performance of the framework for random locations of the users and the interferers are captured using the closed-form expressions. The defect of various power allocation strategies termed as cognitive radio inspired power allocation and fixed power allocation, are performed using MIMO-NOMA. Comparing with the existing MIMO-NOMA work, the model developed yields a performance gain regarding reception reliability.

Di Zhang *et al.* [53] developed non-regenerative massive-MIMO-NOMA relay model models for improving the Spectrum Efficiency (SE) of the system. Additionally, Maximum Mean Square Error-Successive Interference Cancellation (MMSE-SIC) decoding approach is used for interpreting the received information. With the aid of tools in matrix analysis, the closed-form expressions could maintain network capacity and the sum rate. By increasing the SNR value, higher performance can be attained in terms of capacity and sum rate. Moreover, compared massive-MIMO-OMA system, the massive-MIMO-NOMA scheme is capable of achieving improved performance of the system. The advantages can be improved further by increasing the transmitter antenna.

Ming Zeng and Viktoria Fodor [16] designed a model for downlink transmission in MIMO-NOMA systems to solve the issues that occur during power allocation. In this case, the users are already paired to form clusters, creating NOMA clusters, and thereby, sharing equal power. The authors had developed power allocation methods with low complexity in and over the clusters, maximizing the sum-rate and offer required quality of service of the users even for channel condition was weak. While comparing power allocation clusters, the PA approach developed increases the system fairness, without reducing the sum rate achieved in the network.

Yuehua Yu *et al.* [54] addressed the joint Antenna Selection (AS) issues of a classical two-user NOMA system. Two computationally effective algorithms, such as max-min-max AS (AIA-AS) and max-max-max AS (A3-AS) and were developed to improve the sum rate. Under maximum Signal-to-Noise Ratio (SNR) condition, the asymptotic closed-form expressions are obtained for the average sum- rates for these algorithms.

Zhiguo Ding *et al.* [27] have developed the framework used for both uplink and downlink transmissions in MIMO-NOMA, which depends on signal alignment. Based on stochastic geometry, the effect of random locating and interferers of the users has been evaluated using the closed-form expressions. The performance of various power allocation techniques, namely cognitive radio inspired power allocation, and fixed power allocation are analyzed based on MIMO-NOMA system.

Van-Dinh Nguyen *et al.* [55] introduced linear pre coders based on signal superposition at the BS for multi-cellular MIMO-NOMA systems for reducing the sum throughput for meeting the needs of user's QoS. Generally, such an issue is very difficult for the objective function is non smooth and non linear, and the QoS constraints are nonconvex is very challenging. A novel path-following procedure is developed, which produces a simple convex issue of moderate size for every iteration and generate the sequence of enhanced points which assemble to form a local optimum.

Bichai Wang *et al.* [31] developed a mmWave transmission approach for integrating the concept of NOMA using beam space MIMO. The total supported user is greater than the total RF chains attained at similar time frequency resources considering NOMA in beamspace MIMO systems. Reducing inter-beam interference, Transmit Pre-Coding (TPC) approach depends on the ZF principle is designed. In addition, dynamic power allocation is introduced for reducing the achievable sum rate. Furthermore, a complexity iterative optimization approach is low for allocating dynamic power.

Qi Sun *et al.* [56] addressed the issues of sum rate optimization in MIMO-NOMA systems by considering two constraints, such as minimum rate of the weak user and the transmit power, such that the needs of QoS is fulfilled. The CSI condition in MIMO-NOMA system was first derived, to achieve full rate transmission. Depending on the CSI condition, an optimal PA approach was developed for MIMO-NOMA system for attaining the capacity region of the MIMO Broadcast channel. Also, a suboptimal PA method with reduced complexity was introduced for all CSI conditions.

2.1.5 Cluster based techniques

The research works practicing the Cluster based techniques in the MIMO-NOMA systems are discussed below,

Ming Zeng *et al.* [20] examined the Power Allocation (PA) based on its Energy Efficiency (EE) for multi-user MIMO-NOMA system present in a cluster. Assuring Quality of Service (QoS), the system necessity predefining a rate requirement is reduced for every user. Due to the need of QoS, it is crucial for detecting the considered EE maximization issue is reasonable, by analyzing the total transmitted power compared by the power required for fulfilling the QoS. When it is feasible, a closed-form solution had been proposed to solve the issue of sum rate maximization and thereby, the EE maximization problem using nonconvex fractional programming.

Jiefei Ding and Jun Cai [19] developed a linear optimization method in MIMO-NOMA cluster, in which beam forming vectors and coefficients of PA were optimized. The total power consumption was reduced using Mobile User (MU) clustering. During clustering, the technique mitigates the peer effect and could attain a closed-form expression for the cluster beamforming. The technique was employed in two MIMO-NOMA schemes, named MIMO-NOMA2 and MIMO-NOMA 1.

Sunil Chinnadurai *et al.* [57] developed a technique, named Joint User Pairing and Dynamic Power Allocation (JUPDPA), for reducing EE in MIMO-NOMA multicell system. JUPDPA was introduced depending on Euclidean norm and median of the channel vectors. Additionally, the BS assigns the transmitting power dynamically to the set of users.

Purpose in MIMO to NOMA systems is analyzed by Zhiguo Ding [10]. Here, precoding and detection matrices have been developed for downlink transmissions, and the performance of the design has been determined. To overcome the issues identified between conventional OMA and MIMO-NOMA, user pairing was applied to NOMA. Moreover, the performance of the system while applying user pairing was analyzed.

In [58], Sunil Chinnadurai designed a robust beam forming approach for resolving the Weighted Sum-Rate Maximization (WSRM) issues in MIMO-NOMA multi cell system for 5G communications with imperfect CSI at the BS. The method considers imperfect CSI at the BS by accumulating uncertainties for channel matrices using worst-case model, like Ellipsoidal Uncertainty Model (EUM). Additionally, Weighted Sum-Rate Maximization (WSRM) issue is generated for power

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constraints transmitting at the BS. The issues are termed as Non-deterministic Polynomial (NP) issues that is critical for resolving. A robust beamforming technique was developed for establishing Majorization Minimization (MM) approach for finding optimal transmit beamforming matrix and effectively solve the objective issues. Additionally, Joint User Clustering and Power Allocation (JUCPA) algorithm are developed to attain a higher sum rate.

Zhiguo Ding and H. Vincent Poor [59] developed a massive-MIMO-NOMA technique using less feedback. Particularly, the technique could convert a massive-MIMO-NOMA system into various Single-Input Single-Output (SISO-NOMA) channels. Then, the performance analysis for the proposed method is carried out for two scenarios, with one bit feedback and perfect user ordering. Wonjae Shin *et al*. [60] had improved the performance of MIMO-NOMA networks by developing Interference Alignment (IA)-based Coordinated Beam Forming (CBF) methods where two Base Stations (BSs) together optimize their beam forming vectors order for enhancing the data rates of cell-edge users but data sharing among cells are not required. It increases user fairness and spectral efficiency to exploit the approach named capacity-achieving in the downlink.

Md Shipon Ali *et al.* [61] examined the usage of non-orthogonal multiple access (NOMA) based on successive interference cancellation (SIC) in MIMO systems. The receiving antennas at UE are grouped dynamically such that the number of clusters is either same to the number of transmitting BS antennas or higher than the number of BS transmitters. The total receiving antennas that are present in the cluster are shared in a single beam forming vector. A linear beam forming approach is developed to reject the inter-cluster interference. Meanwhile, the receive antennas in every cluster are allocated on the basis of power domain NOMA. The dynamic power allocation solution is applied for the power allocation based on both intra-cluster and inter-cluster in downlink MIMONOMA in order to reduce the cell capacity. Finally, the evaluation is made for performance of the proposed MIMO-NOMA technique.

Xiaofang Sun *et al.* [13] designed a power allocation and beam forming present in multi-cell multiuser MIMO-NOMA network. For downlink transmission, BS utilized coordinated multipoint (CoMP). In this network, the users were grouped depending on the needs of QoS. Particularly, the Group 1 users in are expected to be served with the best-effort, in-spite the Group 2 users need to be served based on the need of target rates. Since the issue formulation is non-convex but it is complicated to solve. Hence, the authors proposed a set of transformations to clarify the issues. Therefore, an iterative suboptimal resource allocation approach depending on convex approximation is developed. For every iteration, Semi-Definite program Relaxation (SDR) was employed to address the rank-constrained optimization issues.

Wonjae Shin *et al*. [18] developed a channel alignment depending on NOMA approach for multi-cell MIMO systems. The total users to be supported by the scheme depend on the values of system parameter, like the number of receiving and transmitting antennas and the total number of cells.

In [62], the rate comparison among MIMO-OMA and MIMO-NOMA has been analyzed by Ming Zeng et al. A PA approach is developed, guaranteeing higher individual rate in MIMO-NOMA than MIMO-OMA by arbitrary power allocation and optimized degrees-of-freedom (DoF). Further, the advantage of individual rate also holds for the case of arbitrary power allocations and equal DoF. Moreover, NOMA achieves better fairness through arbitrary power coefficients.

In [63], Zero-Forcing-Beamforming (ZFBF) technique for a downlink cascaded transmitting is developed by Nibedita Nandan *et al.* to communicate in a two-cell MIMO- NOMA using Cognitive Radio Network (CRN). The limitation on the number of antenna at the transmitter can also be composed by utilizing the ZFBF technique based on signal alignment. The ZFBF system is efficient in maximizing the total secrecy rate.

Chin-Liang Wang *et al*. [64] had developed a MIMO-NOMA downlink system by four users and BS, in which four users are segregated into two clusters. Then, a joint clustering and precoding algorithm is developed to remove the inter-cluster interference for enhancing the sum capacity of the MIMO-NOMA system. This approach involves a high-complexity issue so that a modified clustering and pre-coding algorithms are introduced using channel gain differences among users. By considering Orthogonal Frequency Division Multiplexing (OFDM), the scheme of four-user has been enhanced to the common multiuser in which user of four contributes a subcarrier for transmitting MIMO-NOMA.

Zhiguo Ding *et al.* [65] designed a detection and precoding matrix model in MIMO-NOMA by considering the purpose of MIMO in NOMA systems. Further, the model developed was evaluated to fix a set of power allocation coefficients. For enhancing the performance gap among conventional orthogonal multiple access (OMA) and MIMO-NOMA, paired user has been considered in NOMA systems and its effect based on the performance of the system is identified. To meet several needs in QoS, the cognitive radio stimulation is selected for allocating the power coefficients has also been introduced.

3. RESEARCH GAPS IDENTIFIED

This section deals with the various research gaps and challenges existing in the literature works elaborated, as follows.

The limitations of pilot based techniques are as follows: In [3], SEGWF scheme is introduced for reducing the effectiveness of the optimization issues that reduce average per cell uplink achievable rate of the system. The joint pilot and payload power control scheme have higher error floor level, and hence, iterative receiver is needed to address the floor levels. It does not perform MRC-SIC decoding and thus, failed to select optimal weight [34]. IDACE faced tight curve matching problem and did not consider faster techniques to optimize power [35]. The

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NOMA scheme did not consider the strategy for the application of NOMA in training based systems [36]. The problem faced by massive MIMO is due to the consideration of CSI acquisition at the BS. SINR is defined with cross-cell interference for supplying useful insights based on issues. However, it may be complex in various situations. Power allocation for IDMA is difficult in MIMO IDMA systems. Cooperative and distributive systems are more complicated for sharing CSI among distributed transmitters. Decentralized power control successive interference cancelation (DPC-SIC) is failed to extend MIMO systems [37]. The challenges faced by pre-coding techniques were as follows: MED precoding [39] scheme is hard to execute Dirty Paper Coding (DPC) due to large computational complexity. The design problem is complex due to objective function as it is non smooth and nonlinear and constraints in QoS are non convex for determining the possibilities is challenging [5]. The code design is evaluated using the observation of EXIT chart hence more research is required for analyzing the design theoretically [40]. The major challenges in the beamforming approaches are deliberated as follows: The purpose of the system is to increase the performance of NOMA with less CSI feedback [45]. The developed beamspace MIMO-NOMA failed to consider sophisticated user pairing/clustering [42] in the ultra-dense network (UDN). JUPDPA, developed in [43], is difficult for achieving perfect CSI in fading channels. The challenges faced by sum rate techniques are as follows: Optimal power allocation method [32] adopts two users which is an important limitation in generalization and beam forming. The development of large-capacity VLC systems is a challenge due to the limited modulation bandwidth of the off-the-shelf LEDs for enhancing the VLC systems [47]. Signal alignment based framework [52] suffers from imperfect CSI in MIMO-NOMA systems. The MIMO-NOMA model [52], designed for downlink and uplink transmission failed to consider CSI while designing MIMO-NOMA system. The issues in sum rate optimization failed for including optimal NOMA transmission schemes of multi-cell networks and the optimization of energy efficiency for the MIMO-NOMA systems [56]. Non-trivial problem is the limitation faced by MIMO-OMA [51] while assigning 2 users in the similar cluster in transmitting beamforming vectors. MIMO- Lattice Partition Multiple Access (MIMO-LPMA) failed to analyze the capacity scaling using number of antennas and the users and also, needs more research on imperfect CSI at the transmitter [66,67]. The multi-cell system failed to consider new inter-cell interference in MIMO-NOMA system [61]. The limitation faced by MIMO-NOMA optimization is challenging due to the consideration of power allocation and MU clustering [19]. Joint design of beam forming and power allocation of multicell multiuser MIMO-NOMA network failed to consider the defect of imperfect CSI through the robust optimization [13]. Precoding and detection matrices in MIMO-NOMA systems failed to design least complexity approaches for grouping or dynamic clustering [65].

4. ANALYSIS AND DISCUSSIONS

The analysis and discussion of the distinct research work for the MIMO-NOMA system in accordance to the fading channels, evaluation measures, the number of antennas utilized and implementation tool, are elaborated in this section.

4.1 Based on fading channels

The analysis chart is showing the research papers built for the MIMO-NOMA system based on fading channels, like Rayleigh fading, large-scale fading, small-scale fading, block fading, fast fading, log-normal shadow fading and slow and fast fading is depicted in Figure-2. From the Figure-2, it is conveyed that among research papers, about 16 research papers, i.e. 59%, have used Rayleigh fading channels and 11% of the research works have utilized small-scale fading. The large-scale fading is adopted in 8% of the research's, whereas, 7% of the researches, i.e. 2 research papers, employ block fading channel. Nearly, 4% of the research works are employed with the Log-normal shadow fading, 7% of the papers used fast fading and the slow and fast fading are employed in 2 research works. Thus, it is seen that most of the research papers have used the Rayleigh fading channel in the MIMO-NOMA system.

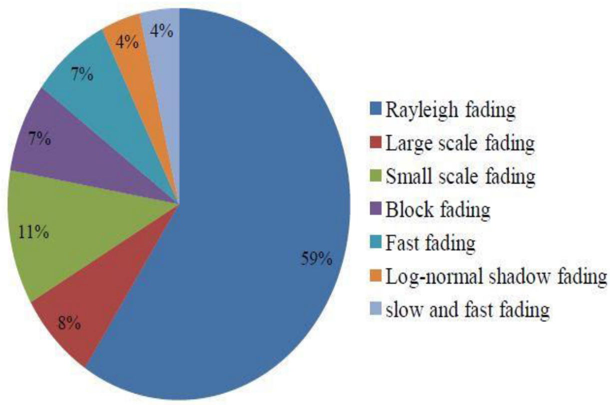

Figure-2. Analysis based on fading channels

4.2 Based on evaluation metrics

The analysis carried out regarding the metrics employed by the distinct research works for the five categories is elaborated in this subsection. Figure-3 depicts the bar chart presenting different metrics used in the existing MIMO-NOMA systems. The commonly utilized metrics in the distinct research works were Sum-rate, Energy efficiency, Bit Error Rate (BER), and throughput. Through this analysis, it is clearly shown that among research papers, about 3 research papers have used throughput, while the sum rate and the other is considered in 16 research papers in total, among which the two papers based on beamforming technique have considered throughput as the evaluation metric. 5 research papers have used energy efficiency and 4 research works have utilized BER as their metric. From the Figure-3, it is conveyed that in most of the research papers, the implementation is done concerning sum rate.

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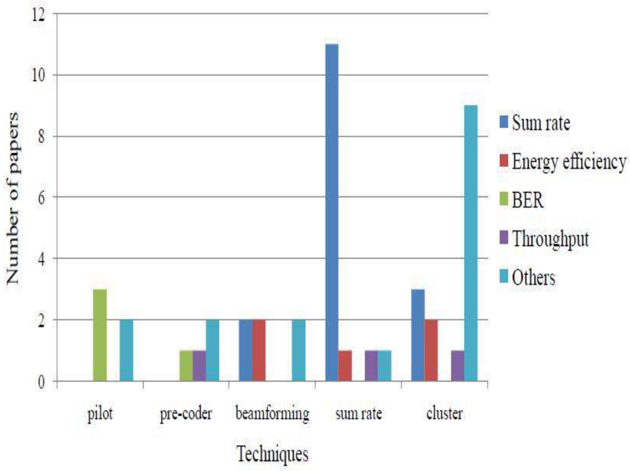

Figure-3. Analysis based on the evaluation metrics.

4.3 Based on the results attained

4.3.1 Sum-rate

The analysis carried out in the aspect of the sum rate in various researches is elaborated. The ranges of sum rate metrics were fixed as 0-10, 10-200 and 200-400 bps/Hz. From the table, it is elucidated that the sum rate value within the range of 0-10 is achieved by 5 research papers and 10-200 range is attained by 2 research papers. The sum rate is attained by the research paper [49] and it is fixed in the range of 200-400.

Table-1. Analysis based on Sum-rate.

Range(bps/Hz)	Number of papers	Reference
0-10	5	[32][44][45][59][62]
10-200	2	[51][53]
200-400	1	[49]

4.3.2 Based on energy efficiency

The analysis carried out in the aspect of the energy efficiency is elaborated in this subsection. From the Table-2, it is elucidated that the energy efficiency value of 11.5 Mbits/Joule is achieved by the technique in [43] and 23 Mbits/Joule is attained in [57]. The technique adapted in [20] had attained the energy efficiency value of 33 Mbits/Joule.

Table-2. Analysis based on Energy efficiency.

Energy (Mbits/Joule)	Reference
11.5 Mbits/Joule	[43]
23 Mbits/Joule	[57]
33 Mbits/Joule	[20]

4.3.3 Based on bit error rate (BER)

In Table-3 represents the analysis made by concerning the BER in different research works. From this analysis, it is visualized that the BER value of [34] is $<10^{-3}$ dB and 3 research works, [35], [40], and [37] have the BER value of 10^{-5} dB.

Table-3. Analysis based on BER.

BER(dB)	Reference
$<10^{-3}$	[34]
10^{-5}	[35] [37] [40]

4.4 Based on the number of antennas

The analysis carried out in the aspect of the antenna range used in the existing works is elaborated in this subsection using Figure-4. From the figure, it is explored that the antennas in the range of 1-250 is employed in 31 research papers, i.e., 3 research papers in the pilot based techniques, 4 research papers in the pre-coding based techniques, 8 in the sum rate based techniques, while 4 and 12 papers in beam forming and cluster based techniques have used the antennas in the range 1-250. The number of antennas in the range 250-500 is utilized in 2 research works that are based on the techniques, beamforming and sum-rate. Then, antennas in the range 500-750 is used in 1 research work that is based on the sum rate technique and again, 1 research paper (pilot based technique) attained the accuracy range of 750-1000.

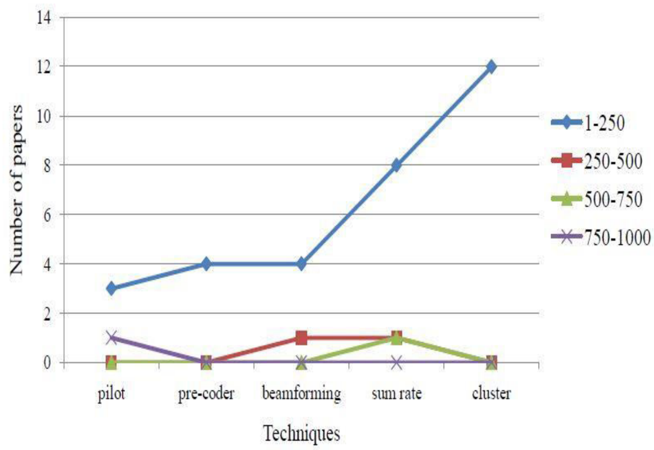

Figure-4. Analysis based on number of antennas.

4.5 Based on implementation tools

This subsection deliberates the analysis carried out considering the simulation tools employed in the research papers. Table-4 displays the distinct implementation tools employed in various MIMO-NOMA systems. The commonly practiced implementation tools are CVX, MATLAB, LTE-Advanced and YALMIP. From Table-1, it is clearly shown that the CVX tool is the commonly adopted implementation tool for MIMO-NOMA systems.

5. CONCLUSIONS

A survey on different schemes employed for MIMO-NOMA systems is elucidated in this paper. The primitive goal of this article is to review, categorize and learn the techniques utilized for the MIMO-NOMA systems through the analysis of research papers from IEEE, Google Scholar, Elsevier and Science Direct. The analysis and discussion were made concerning fading channels, metrics, number of antennas used and implementation tool. The existing approaches have been surveyed under the categories, like pilot-based techniques, pre-coder based techniques, beam forming based techniques, sum rate based techniques and cluster based techniques. Also, this survey provides the research gaps and issues found in various MIMO-NOMA techniques that are discussed in the literature. In accordance with the discussion and analysis, it can be concluded that the sum rate is the widely concerned evaluation metric in several research studies in the MIMO-NOMA system. The vastly adopted fading channel is Rayleigh fading and the frequently employed implementation tool is CVX.

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