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A REVIEW OF NEW IMPROVEMENTS IN RESOURCE ALLOCATION PROBLEM OPTIMIZATION IN 5G USING NON-ORTHOGONAL MULTIPLE ACCESS

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ABSTRACT

Because of the arising requirements of emerging networks (Fifth-generation and beyond) such as supporting diverse Quality of Services (QoS), low latency, and high spectral efficiency; the previous and traditional generations of communication systems are becoming inappropriate. Furthermore, due to the huge connectivity and ever-growing demands of diverse services and high data rate applications, more effective radio access techniques are required for the purpose of a full-scale implementation of the fifth-generation (5G) and beyond wireless systems. Therefore; the researchers are looking for new mechanisms to accomplish these demands, and one of the key techniques been proposed is NOMA due to its capability of spectrum efficiency enhancement. In NOMA-Based systems, the information signals of various users are superimposed at the transmitter side, by utilizing the differences of channel gain to work for different users simultaneously. In this study, recent papers on resource allocation problems based on Power-Doman NOMA (PD-NOMA) in 5G networks were reviewed and the goal (objective function), optimization methods used and obtained results of each analyzed paper are investigated. In addition, the discussed resource allocation problems were classified into optimal rate problems and power/energy-efficient problems, and the proposed solutions in each of them are analyzed. Finally, this study highlights some of the present and future challenges in this field.

KEY WORDS: 5G, Energy-Efficient (EE), Non-orthogonal multiple access (NOMA), Optimization, Resource Allocation.

1. Introduction

Orthogonal Multiple Access (OMA) techniques have been used in traditional and current cellular network systems. Where Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), and Orthogonal Frequency Division Multiple Access (OFDMA) have been used in first-generation (1G), second-generation (2G), third-generation (3G), and fourth-generation (4G) of cellular network systems respectively [1]. The common feature of these various OMA techniques is orthogonality, which prevents Inter-Users-Interference (IUI) when the network resources are accessed by different users. For emerging networks such as (5G), these OMA techniques cannot achieve the required demands, because these techniques are not adequate to support a very large number of users, emerging wireless applications with massive connectivity and different Quality-of-Service (QoS) demands, and extremely high data rates [2]. To overcome this obstacle, another multiple access technique known as Non-Orthogonal Multiple Access (NOMA) has been introduced. In NOMA, the same block of resources (i.e.: frequency, time, etc.) can be shared by different users simultaneously, but on the other hand, they are separated in other domains (i.e.: power). Better spectral efficiency, low latency, and higher throughputs at the cell edge are among the main advantages of NOMA, but with the cost of more complexity at the receiver side

[3]. Power Domain NOMA (PD-NOMA) and Code Domain NOMA (CD-NOMA) are the two main categories of NOMA [4]. In PD-NOMA, different levels of power are assigned to different users based on their channel conditions. In CD-NOMA, different codes are assigned to different users over the same block of resources (i.e.: frequency, time, etc.) [5]. On the other hand, as the performance of the system is extremely affected by the way of allocating the available resources (frequency, time, etc.) to the end-users, more attention is given by researchers to the resource allocation problem in cellular networks. Resource allocation is the fundamental domain to attain the full possibility of communication systems with NOMA [6]. In this paper, new and up-to-date papers dealing with the resource allocation problem for PD-NOMA will be reviewed and analyzed. The remaining of this paper is organized as follows: Section II. covers the basic concepts of NOMA (especially PD-NOMA). A review of recent papers on the resource allocation problem is presented in section III. In section IV, the main challenges in this field are provided and discussed. Finally, section V concludes the paper.

2. BASIC CONCEPTS OF NOMA

The initial reason behind the introduction of PD-NOMA was spectral efficiency improvement of wireless networks. It improves that by providing a full degree of freedom (sharing both time and frequency domains) with multiple users at the time when each user is allocated with only a specific level of power. Different levels of power are assigned to different users at the transmitter side via Superposition Coding (SC) [7]. The main principle of SC is to encode different signals prepared for different users with different levels of power at the transmitter side (multiplexing in power domain at the base station) and to help the receiver to perform the process of multiuser detection successively [8]. On the other hand, on the receiver side, all the users receive the superimposed signal (their intended signal in addition to the interference caused by the signals of other users). For each Successive Interference Cancelation (SIC) receiver (user), to receive its desired signal, the SIC process is performed. SIC means that the intended receiver first decodes all the stronger signals than its desired signal (all dominant interference), subtracts them from the superimposed signal sent by the transmitter, and then decodes its own signal [9]. To explain the idea in more detail, a case of two users is considered for both Downlink (DL) and Uplink (UL) of NOMA.

For DL-NOMA, the Base Station (BS) sends the superimposed signal to both users. Figure 1 shows the scheme of two-user down-link PD-NOMA. In this scenario, the signals of both users are superimposed upon each other with different levels of power assigned to each user at the transmitter side. Based on the NOMA principle, lower power is assigned to the signal of the user that has a better (strong) channel gain, and higher power is allocated to the signal of the user that has a worse (weak) channel gain. Then, at the receiver side, the strong user is required to perform the (SIC) process, because the weak user's signal is of higher power than its own signal. Therefore; the strong user can successfully decode the signal of the weak user first, subtract it from the superimposed signal, and then decodes its own signal. On the other hand, at the weak user receiver, no (SIC) is needed, because the strong user's signal is of lower power than the desired signal of the weak user, so the weak user will deal with the strong user's signal as noise when decoding its own signal, therefore; the weak user will decode its own signal directly without (SIC).

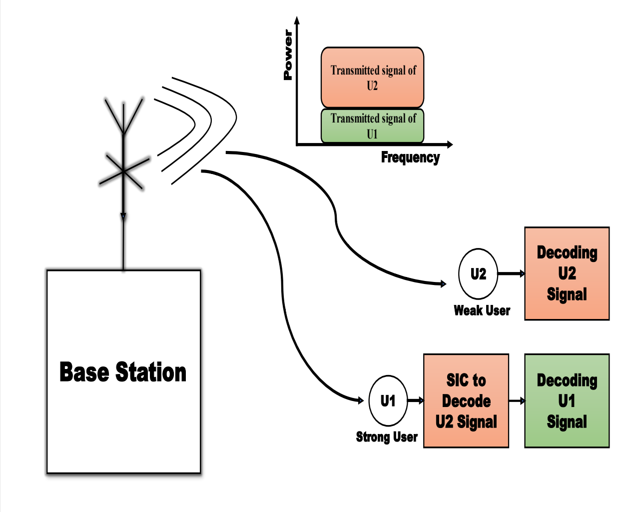

Figure 1. The Scheme of DL-NOMA for Two-user

For the UL-NOMA scenario, the two users send their signals to the BS with different levels of power based on their own channels' conditions with respect to the BS. Then, when the superimposed signal containing the signals of both users arrives at the BS, it decodes the strongest signal first, subtracts it from the received (superimposed) signal, and then decodes the other signal (weaker signal). Figure 2 shows the scheme of two-user up-link PD-NOMA.

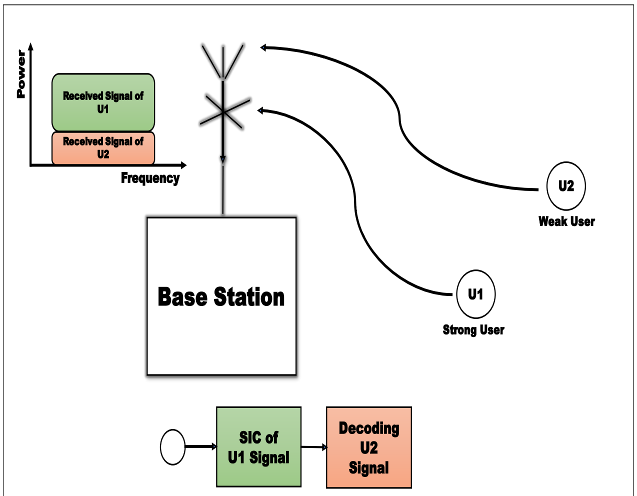

Figure 2. The Scheme of UL-NOMA for Two-user

2. RESOURCE ALLOCATION

Resource allocation is the fundamental domain to attain the full possibility of communication systems with NOMA [6]. Efficient power allocation and optimal users clustering are the two important resources of great interest for researchers in NOMA-Based systems. Different optimization methods exist to solve the resource allocation problems and the appropriate method can be chosen based on the nature of the objective function and the given constraints raised from the allocation scenario. Some of these optimization approaches are combinatorial optimization approach (help in transforming the originally non-convex problem to a convex one), Convex optimization approach (solve convex problems), and matching theory approach (problems of beneficial relationship nature) [1]. The type of obtained solutions (results) depends on the optimization method used. Some methods give global optimal solutions but with high computational complexity while other methods give approximate solutions with low computational complexity [10]. In this paper, the problem of resource allocation for PD-NOMA based on three of the performance metrics, namely achieved rate, power, and energy has been studied.

2.1 OPTIMAL-RATE AND POWER/ENERGY-EFFICIENT RESOURCE ALLOCATION

In this work, the recent improvements in the resource allocation problem to maximize the sum rate (spectral efficiency), and to minimize the power and energy with PD-NOMA in communication systems is studied and several new and up-to-date related papers are analyzed and reviewed. To simplify the analysis of the studied problem, the resource allocation is divided into optimal-rate resource allocation and power-efficient or energy-efficient resource allocation:

2.1.1 OPTIMAL-RATE RESOURCE ALLOCATION

In this sub-category of resource allocation, the objective is to maximize the achievable rate (spectral efficiency). In [11], the objective was to allocate power among users optimally such that the weighted sum rate of a downlink NOMA network is maximized, the rate is also taken into consideration as a constraint to ensure the QoS and guarantee successful SIC decoding. The WSRM problem is solved in two stages, at the beginning, the authors derived a closed-form solution for a two-user WSRM problem. Then, the obtained results from first stage are used by the authors to implement a new power allocation algorithm for a scenario of multiple users. The closed-form solutions of the first stage were given for scenarios of different weight ratios and the algorithm proposed for the second stage was shown to provide optimal solutions, and the solutions can be obtained for the different scenarios of all users' weight ratios. Their simulation results show that the values of WSR are better than some of the existing works in literature and in worst cases they are equal to that of some other related works. But, according to the authors, this had been obtained at a low complexity if compared with the existing works in literature. Moreover, the proposed power allocation scheme by them shows a stable performance of SIC due to the given QoS constraints, and the comprehensive simulations confirmed the effectiveness of their algorithm.

In [12], the authors proposed a weighted sum-rate maximization problem in a downlink multi-carrier NOMA system with a constraint of power consideration. According to the authors, although this problem is a Non-Deterministic Polynomial-time hardness (NP-hard) problem to solve, the previous works have used either heuristics methods with no theoretical performance guarantee or algorithms with impractical computational complexity. As a result, they have proposed their novel framework, where the basic problem is divided into two polynomial-time solvable sub-problems known as:(1) "The Multi-Carrier Power Control (MCPC) sub-problem", and (2) "The Single-Carrier User Selection (SCUS) sub-problem". The first sub-problem is nonconvex, but they could solve it by using an optimal and low complexity two-stage algorithm (MCPC) based on the projected gradient descent method. While the second sub-problem is a nonconvex mixed-integer problem that has been solved via dynamic programming (SCUS). So, they have developed an efficient scheme called (JSPA), to tackle the joint subcarrier and power allocation problem. In other words, the two solved sub-problems which act as a basic building block to facilitate the main algorithm design are then combined by the authors to solve the general WSR maximization problem based on an efficient heuristic (JSPA) scheme. To obtain their results, a downlink MC-NOMA system with a single base station and multiple users is considered. They assumed that the total system bandwidth is equally divided among the multiple subcarriers and there is no interference between the adjacent subcarriers. They compared their obtained results from the proposed scenario to that of several researchers from related works to evaluate the WSR. The numerical results of this work indicated that it can achieve fairness among the users, obtain near-optimal sum-rate, and offer more improvements in performance when compared to OMA techniques.

The authors of [13] investigated a subcarrier and power allocation problem for the downlink of a single-cell MC-NOMA system. In the literature of this work, the maximization problem has been proved to be the NP-hard ((Non-deterministic Polynomial-time hardness) problem, and Lagrangain duality and dynamic programming (LDA) based near-optimal polynomial-time solutions have been proposed. In this work, an iterative water-filling algorithm has been designed which is more efficient in terms of time but with a small degradation in sum rate. Because the sum-rate performance is mainly affected by subcarrier allocation and power control for multiplexed users, they have proposed their algorithm as a 3-step algorithm to address the sum-rate maximization problem. In the first two steps, subcarriers are assigned to users based on Synchronous Iterative Water-filling Algorithm (SIWA). Then, based on that, SIWA is used again to allocate power to users in the third step. In the initial step, they supposed that all the subcarriers can be used by each user at the same time, then, they applied SIWA to assign power to each user. In the next step, to reduce the complexity of the receiver and the possibility of propagation errors due to SIC, they have assigned each subcarrier to only two users at most via a heuristic greedy method. In the last step, to further enhance the system performance with the subcarrier allocation results acquired from the previous step, they applied SIWA once again. They could prove the convergence of their proposed algorithm (SIWA) in the last step (step3) but with a constraint that no more than two users are multiplexed together. The authors called their proposed 3-step method, Double Iterative Water-filling Algorithm (DIWA) because they have applied the SIWA algorithm twice. DIWA is considered as a competitive algorithm to LDA, but with much lower computational complexity. For simulation purposes, they have considered a downlink MC-NOMA system model with a single base station and multiple users. They assumed that the total system bandwidth is equally divided among the multiple subcarriers and there is no interference between the adjacent subcarriers. Simulation results of their study indicated that their proposed strategy could achieve comparable data rates performance to an existing near-optimal solution (LDA) but with lower computational complexity.

2.1.2 POWER-EFFICIENT OR ENERGY-EFFICIENT RESOURCE ALLOCATION

The aim of this sub-category of resource allocation is to minimize the power/energy needed for communication systems via sustainable management techniques. The optimal allocation of these resources minimizes the costs (expenses) and also reduces its effect on climate, environment, and living beings [14].

In [15], the authors proposed power-efficient resource allocation for (MC-NOMA) systems with Imperfect Channel State Information at the Transmitter side (I-CSIT) and (QoS) requirements of users are taken into account in the proposed framework. In traditional multi-carrier systems, each user was allocated with a single sub-carrier while for MC-NOMA systems, each subcarrier could be allocated to multiple users. In this study, they assumed that each of the subcarriers can be allocated to at most two users via NOMA in order to reduce the computational complexity and delay incurred at receivers due to SIC decoding. Furthermore, to simplify the optimal SIC decoding policy design per each subcarrier, they have defined an outage threshold by a channel/noise ratio, and based on that outage probability, they have defined the QoS demand. They do that due to the fact that under perfect CSIT, it is known that the decoding order of optimal SIC is descending based on the gains of the channels. While, for imperfect CSIT, the decoding order of SIC cannot be determined via the comparison between the actual channel gains of the multiplexed users. The proposed resource allocation algorithm by the authors of this study is formulated as a non-convex optimization problem. The proposed algorithm resolves the power allocation, user scheduling, and SIC decoding policy for the purpose of total transmit power minimization. The original non-convex problem is adjusted to a generalized linear multiplicative programming problem, then the branch-and-bound approach is applied in order to obtain a globally optimal solution. Because of its high computational complexity nature, the optimal resource allocation policy works as a criterion for system performance. So, to make fairness between computational complexity and the performance of the system, a difference of convex programming-based suboptimal iterative resource allocation algorithm is proposed by the authors. Their results of simulation show that the latter proposed scheme (suboptimal scheme) attains a near-optimal performance and outperforms the traditional OMA schemes in terms of significant transmit power savings.

In [16], the authors investigated a power-efficient resource allocation problem in Virtualized Wireless Networks (VWNs). VWNs means that the infrastructure of the physical network is shared among different service providers. Now, with virtualization the network will become as a set of slices, and the most significant challenge is to prevent a user from a specific slice to affect the users of other slices. VWN technique is considered as a promising technique that can be used to improve the spectrum efficiency. In this study, the authors tried to examine if the performance of a VWN network will improve in terms of power efficiency in case NOMA is used. To do that, the authors proposed two transmission modes and made a comparison between them. In first transmission mode, NOMA is used, which means that the total band (frequency) 0f interest is divided among the users. While in second transmission mode, they used OFDMA, which means that the bandwidth is first divided into a set of subchannels (subcarriers), and then each subchannel is assigned to at most one user at the same time. They formulated their problem with an objective of total transmit power minimization under the constraint of keeping the least desired capacity for each slice. But the challenge that they face is that the problem is a non-convex optimization problem that is complex and not easy to solve. For NOMA-based transmission mode, they proposed an efficient algorithm to solve the problem by applying complementary geometric programming and variable relaxation to transform the problem into a geometric programming. Then, for OFDMA-based transmission mode, they applied the relaxation technique first and then the Lagrange dual function in order to solve the original problem. Their obtained results from different simulation scenarios proved that NOMA outperforms OFDMA in terms of power efficiency. They show that the power efficiency was improved by about 50% when NOMA is applied rather than OFDMA.

In [17], a user pairing and energy-efficient allocation of power scheme for a Down-Link NOMA wireless network is proposed by the authors. The objective function of their optimization problem is the maximization of the system's total EE with considering the total power as a constraint. The problem is divided by the authors into two sub-problems, the channel pairing sub-problem and power allocation sub-problem. They started first with the channel pairing sub-problem in order to obtain the optimal scheduling of users, and then, they started to search for the optimal power allocation based on the results obtained from the first sub-problem. In the first sub-problem, they considered a scenario of two users for each subchannel and made use of the "channel state sorting-pairing algorithm". Based on this algorithm, the user of the best channel condition is paired with the user of the worst channel condition. The aim of this algorithm is to increase the sum-rate of the system and decrease the inter-user interference between users of the same subchannel. Next, the power allocation sub-problem is performed on two stages by the BS: power allocation for multiple users per subchannel stage, and power allocation for various subchannels. In first case, the authors considered a two users' subchannel with a fixed power allocation, then they found the optimal power allocation rate between the two users with the goal of maximizing the subchannel transmit rate. While for second case, the problem is non-convex and it is very complex to be solved directly, therefore; they converted it into Dinkelbach representation and an algorithm was proposed to obtain the optimal solution. At the end, they performed their simulations and the results obtained from their proposed scheme had been compared with that of an OFDM scheme from the literature. They could prove that their NOMA-based proposed solution is more energy-efficient than OFDM.

In [18], an energy-efficient resource allocation scheme in multicarrier NOMA (MC-NOMA) systems with fairness is proposed by the authors. They worked on a scenario of a downlink MC-NOMA network by assuming that a single base station serves multiple users through a set of subchannels (sub-carriers). The aim of this paper is a joint optimization of energy efficiency and fairness among users by considering the subcarrier and power allocation parameters. Because the optimization problem was of high computational complexity and non-convex, therefore, the authors formulated it to a two-stage problem known as the subcarrier assignment problem and the power allocation problem. For the subcarrier assignment problem, they proposed a novel greedy subcarrier assignment scheme based on the worst-user first principle to maximize the energy efficiency of the user with the lowest performance. The proposed greedy scheme is also used to assign two users on each subcarrier in order to reduce the computational complexity furthermore. On the other hand, the power allocation problem is also a non-convex and NP-hard problem because of the fractional nature of the energy efficiency formula and the presence of interference. To simplify the solution, the non-convex problem is transformed into a simpler subtractive form using fractional programming, and the new convex sub-problem is iteratively solved by applying sequential convex programming which leads to a suboptimal allocation of power through the subchannels. They compared their obtained results to baseline schemes of related works, their provided simulation results have shown that the proposed resource optimization method achieves fast convergence in terms of EE, guarantees fairness among users, and it is of low complexity.

The authors of [19] proposed a joint resource allocation algorithm for Device-to-Device (D2D) Communications systems Based on NOMA as both the latter have a great impact on the performance improvement of the future mobile communication system. The objective of their proposed algorithm known as joint subchannel and power allocation is the maximization of the EE and throughput of the uplink mobile communication system. Because the efficiency and total throughput of the NOMA-based D2D communication systems can be hugely improved if the interference between the cellular users and D2D users is reduced, therefore; the authors proposed an algorithm to apply the Kuhn-Munkres (KM) technique in order to assign the channels of the cellular users per every individual D2D group based on the interference situation between the D2D users and the cellular users. Then, in each individual group, based on NOMA principles the power rates of the weak and strong users are obtained using the Karush-Kuhn-Tucker (KKT) conditions. In their designed algorithm of maximizing the EE of the system, the constraints of all users’ QoS guaranteeing and maximum transmit power of the D2D users were considered. They considered a scenario of an uplink transmitting in a single cell with the base station at the cell center. Multiple groups of D2D and multiple cellular users per cell are considered. They also assumed that the channels are allocated for each user via an algorithm carried out at the base station called the channel allocation algorithm. Their scenario is designed such that there is no inter-group interference (between different D2D groups) and only intra-group interference exists (within each D2D group and cellular users of the multiplexed channel). They compared their results with that of many other related types of research, under different network conditions, the simulation results showed that the algorithm proposed in their study outperforms the traditional ones in terms of EE and throughput.

2.2 DISCUSSION

After the review of all the analyzed papers is accomplished, it can be noticed that each paper of them has utilized the available resources in order of a specific goal achievement. In addition, it was clear that the chosen strategy in each paper is selected based on the studied situation and the proposed algorithms and obtained results of each of them outperformed the existing algorithms and solutions of the related works in literature. To simplify the comparison between the various papers that been reviewed, the link type (downlink or uplink), the treated resources, the optimization method that has been applied to solve the problems, and the main results of each paper are presented in Table 1.

Table 1. Comparison Among the Different Papers of

Literature

Reference No.	Category	Link-type	Allocated Resources	Optimization Algorithm / Method	Main Outcomes
[11]	Optimal-Rate	Downlink	Power allocation	N/A	Better WSR than the existing works in literature is obtained with low complexity and stable SIC.
[12]	Optimal-Rate	Downlink	Joint subcarrier and power allocation	Heuristic method named as: (JSPA)	User fairness and near optimal WSR are obtained through the proposed algorithm
[13]	Optimal-Rate	Downlink	Joint subcarrier and power allocation	Iterative DIWA algorithm	Achieved comparable data rates to an existing near-optimal solution (LDA) with much lower computational complexity
[15]	Power Efficient	Downlink	Joint user scheduling and power allocation	Iterative algorithm based on difference of convex programming	Near optimal performance and the obtained solutions outperform the traditional OMA scheme
[16]	Power Efficient	Downlink	Joint subcarrier and power allocation	A complementary geometric programming-based algorithm	The proposed algorithm outperforms OFDMA in terms of power efficiency
[17]	Energy Efficient	Downlink	Joint user scheduling and power allocation	channel state sorting-pairing algorithm and Dinkelbach based algorithm	The proposed algorithm outperforms OFDM in terms of energy efficiency
[18]	Energy Efficient	Downlink	Joint subcarrier and power allocation	Greedy algorithm, and fractional programming and iterative sequential convex programming algorithm	proposed scheme achieves fast convergence in terms of EE, guarantees fairness among users, and it is of low complexity in comparison to baseline schemes of related works
[19]	Energy Efficient	Uplink	Joint subcarrier and power allocation	Kuhn-Munkres (KM) technique-based algorithm and Karush-Kuhn-Tucker (KKT) conditions-based algorithm	Their algorithm outperforms the existing literature works in terms of EE and throughput

3. CURRENT AND FUTURE CHALLENGES

Emerging and future networks such as 5G and beyond 5G networks, face challenging requirements emerging from the anticipated use scenarios including IoT, low latency or real-time communications, and enhanced mobile broadband [20]. NOMA (PD-NOMA) alone cannot fulfill such huge demands, therefore; there is a need to combine more technologies with PD-NOMA to accommodate these challenging demands. Only the resource allocation for the PD-NOMA problem has been studied in this paper, but in fact, several other technologies are needed to be addressed and integrated with NOMA in order to accommodate the demands of future networks (5G and beyond). From these technologies are millimeter wave (mmWave) communications [21], multiple-input multiple-output (MIMO) and massive MIMO (mMIMO) [22], cooperative communications, and coordinated multi-point (CoMP) transmission and reception [1]. Eventually, the combination of these various technologies is a real challenge and there is a lot of research work about it nowadays. Although, this topic has gotten too much attention by the researchers, but there are still a lot of issues which are new and not explored well, and as a result, there is a wide range of directions for research in these fields. Therefore; this challenge remains open and can be considered as a future challenge too.

In addition to the aforementioned technologies, the integration of cloud radio access networks (C-RAN) with NOMA also has a significant role in the potential performance enhancement of 5G and beyond systems [23]. One of the reasons behind considering C-RAN architecture is the lack of traditional distributed networks in terms of global network information, they deal with only local network information. In this recent architecture, a cloud-based processor (central) is responsible for users scheduling, as a result, higher spectral efficiency (SE) can be achieved due to the centralized scheduling approach in contrast to the achieved (SE) with a decentralized approach which is lower due to the lack of global information. Furthermore, the huge number of services that vary in their requirements and the types of their devices. The movement from the traditional communications systems to those including various kinds of communications related to machines (mostly known as machine-type communications) require the networks to change its forms according to the 5G systems' view of the oriented services. To fulfill this service-oriented view, there is a need for a new norm of mobile network architectures such as Software Defined Networks (SDN) and Network Function Virtualization (NFV). These programmable, more flexible, and very effective frames permit the network slicing concept on per-service principle. Where (SDN) is a new network architecture that separates the tight coupling between the control plane and the data plane that exists in traditional networks in order to enhance the data forwarding efficiency, and the controllability, security, and management of network resources [24]. While (NFV) is a technology that enables each network function to run as a virtualized network function (VNF) on hardware which is originally general-purpose hardware for the aim of deployment costs reduction [25]. In summary, the integration of these two recent technologies can provide a large number of diverse services across the underlying and permanent physical infrastructure [26].

4. CONCLUSION

In emerging networks such as 5G, the design of efficient resource allocation is the major challenging target. In this paper, PD-NOMA based resource allocation problem literature was reviewed and the goal (objective function), optimization methods used, and results of each analyzed paper is investigated. Consequently, this study provided a comparative table of the advanced techniques and optimization methods on resource allocation problems and highlighted the current and future challenges in this field. In literature, the need for resource allocation techniques was considered and different approaches were proposed based on three of the performance metrics, namely achieved rate, power, and energy because these performance metrics have a significant impact on emerging wireless networks. The analyzed and reviewed papers included the recent improvements in the resource allocation problem to maximize the sum rate (spectral efficiency), and to minimize the power and energy with PD-NOMA in communication systems. However, in fact there is a trade-off (increasing one metric decreases the other) relationship between SE and EE which has not been considered in literature. Therefore; the analysis and mathematical modeling of the SE-EE trade-off relationship in NOMA-Based systems is of great importance. As a result, to attain an elastic SE-EE trade-off relationship (make a balance between the two conflicting metrics) in emerging wireless networks, we will focus on SE-EE trade-off problem in DL-NOMA systems in the future. This critical problem needs to be formulated as an optimization problem with the objective of maximizing the EE under the constraint of satisfying a minimum SE demand. Furthermore, the QoS demands of the end-users need to be determined and satisfied by a requirement of minimum data rate.

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