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A Review of Power Domain Non-Orthogonal Multiple Access in 5G Networks

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Abstract: This paper highlights the fundamentals of the strong candidate Power Domain Non-Orthogonal Multiple Access (PD-NOMA) technique, and how it can best fit the requirements of fifth Generation (5G) in practical applications. PD-NOMA ensures flexibility in radio resource to improve user's access performance. Multiple users share the same radio resources in PD-NOMA, and therefore better spectrum efficiency can be achieved. The practical system design aspects of PD-NOMA are considered in this paper by exploring different network scenarios. Optimal performances of PD-NOMA system can be obtained by suitable power allocation schemes, with reduce the computational complexity, and advanced user pairing strategy. Theoretical formulation and solutions are also explained prior to the concept of downlink PD-NOMA. Challenges and future research windows are discussed before conclusion of this paper.

Keywords: Power domain, NOMA, 5G, successive interference cancellation, user pairing

1. Introduction

It is a recognized fact that approximately every 10 years a new wireless communication network standard emerges to cope with the massive growth of digital devices worldwide. So far, the current wireless communication network standard, 4G LTE has been found not to possess enough capabilities to cope with the required massive connectivity that will come into play in the years to come with the surge in development of computational devices, mobile devices, Internet of Things (IOTs) as well as large-scale cloud connectivity. In contrast, with this high demand level, the available frequency resources are not sufficient and quite limited. That encourages industries, academia and researchers to work on developments of 5G wireless network standard addressing the following challenges:

- High data rate 1000x of current 4G.
- Enhanced user quality of experience (QoE).
- Low round trip transmission (1ms latency).
- Lower energy consumption.
- Massive connectivity with diverse quality of service (QoS) million devices/square km.

An all-encompassing vision of 5G wireless networks can be outlined as such:

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- A highly efficient mobile network that guarantees optimal performance at lower investment rate. It should meet the highly desirable need for the unit cost of data transportation varying inversely as the volume of data demanded to be the most pressing need for mobile network operators.
- An ultra-fast mobile network consisting of the next generation of small cells tightly assembled together to give constant coverage over, urban areas (in the worst case scenario), and drives the world to the final frontier for true “wide area mobility” It would require access to frequency under 4GHz.
- A fibre-wireless network that introduced recently for wireless internet access. The millimetre wave bands (20 – 60 GHz) also allow wide bandwidth radio channels to support data access speeds of up to 10 Gbit/s.

In order to concretize a roadmap for achieving the 5G network’s vision, initiatives research carried out a few years ago extensively worldwide in order to take a step further in shaping the future of mobile and wireless networks beyond 2020. Until recently, Orthogonal Multiple Access (OMA) techniques have always been the default approach for achieving a decent level of throughput performance in packet domain services with a simplified receiver design, which has characterized the radio access technologies for cellular mobile communication [1, 2]. Moreover, 5G networks should have the ability to support communications for certain special scenarios that are not supported by 4G networks. As such, 5G wireless systems are expected to provide high data rates (network level 10-20Gbps and user experience data rate of 1Gbps), improve the user Quality of Experience (QoE), enhance latency (1ms round-trip latency), and lower energy consumption [3,4]. Despite all these benefits, a typical challenge facing 5G wireless systems is the spectral efficiency in handling heavy traffic from mobile internet usage. Another challenge is with the development of the Internet of things (IoT) specifically, how to connect users and devices in such a way to ensure low latency and diverse service types. In conventional OMA schemes, the overall amount and the scheduling granularity of orthogonal resources determine and limit the number of supported users, therefore, in addition to range of enabling techniques, such as cell densification and utilization of new spectrum, advanced radio access technique is the most beneficial to increase the system capacity in 5G networks [5].

NOMA is a potential multiple access solution for the next generation of wireless systems having a superior spectral efficiency which is laying in exploits a smart reuse of the network resources. It could rely on the new domain that is not yet been utilized in a previous wireless generation, such as power and code domain. NOMA allows more than users to share the same resource by multiplexing multiple users’ messages in the same sub-carrier at the transmitter side and constructing effective multi-user detection (MUD) techniques at the receiver side. Compared with OMA, NOMA will face the great challenges of achieving much higher spectral efficiency, massive connectivity and ultra-low latency for the future 5G wireless systems.

In general, the two basic techniques that play an important role to make NOMA exist is the superposition coding (SC) and successive interference cancellation (SIC), i.e.; allows the superposition of two or more different user’s data transmission at the transmitter side and detect and encode the received message signal at the receiver side by applying SIC. Therefore, the cell-centre users and cell-edge users are broadly categorized at the base station depending on their channel gain conditions. Users are co-scheduled onto the same radio resource by setting a threshold coupling loss to complete PD-NOMA user pairing. The cell-centre or cell edge UEs are identified by comparing the coupling loss with the configured threshold. This process reduces the computation complexity for the practical scheduler followed by the allocation of power to the co-scheduled NOMA users. Finally, the base station runs the scheduling decision, for instance, in the case of determining proportional fairness for multiple users. This step results in the selection of the set of users and the associated power allocation ratio prior to the selected scheduling algorithm. The interference cancellation (IC) receivers are introduced in LTE-Advanced Released 12 to handle inter-cell and intra-cell interference. The IC, therefore, makes it feasible for user implementation to reduce the intra-cell and inter-user interference in NOMA systems.

There are two main categories of NOMA techniques, namely code-domain multiplexing (CDM) and power domain multiplexing (PDM). The CDM-NOMA facilitates user separation at the receiver by introducing redundancy via coding/spreading. Whereas, PDM-NOMA is able to perform successive interference cancellation (SIC) for users with high channel gains. In this sense, power domain NOMA (PDM-NOMA) ensures flexibility in resource allocation to improve NOMA performance. Nevertheless, comprehensive knowledge of the recent research achievements is extremely desirable since NOMA is still in its middle stage in 5G wireless systems. In this regard, this review paper mainly focuses on PD-NOMA access protocol in the facets of technical issues in a single cell and multi-cell environments.

The rest of this paper is organized as follows: Section 2 introduces the working principles of a typical PD-NOMA system in a single cell environment in both uplink and down link scenarios. Furthermore, working principles and inter-cell interference existence in multi-cell PD-NOMA environment are explored. Then the limited research work on PD-NOMA in the multi-cell environment is summarized. Section 3 explains the PD-NOMA power control, channel allocation and user pairing aspects. Section 4 describes the combination of MIMO with NOMA performance evaluation. Challenges and future research are discussed in Section 5 before concluding the paper in last section.

2. Working Principles of PD-NOMA Systems

2.1 PD-NOMA in Single Cell Environment

As a technology, NOMA has the potential to adequately meet 5G network requirements. PD-NOMA mechanisms mainly rely on multiplexing different users by allocating different power level to each of them according to their channel gains to ensure a high system performance [6-8]. Many research efforts undergone to ascertain the maximum benefits of utilizing PD-NOMA system for both downlink/uplink setting, with different aspects and scenarios. It is essential to consider the practical system design aspects in order to ensure that the PD-NOMA features are feasible in real networks.

A typical single-cell down-link PD- NOMA system is considered here with two users UE outlining the transmitter and receiver operations. Fig. 1 shows that both users, $UE1$ and $UE2$ belong to the same cell, scheduled on the same radio resources, frequency and time, with their modulated symbols directly superposed.

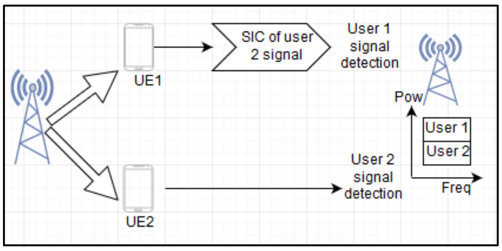

Fig. 1 – PD-NOMA Transmitter Setup

Typical consideration of a single cell scenario, transmitter and receiver antennas is assumed in [9] to explain the concept of downlink PD-NOMA, $\boldsymbol{N}$ users' equipment U_i, with $i \in N = \{1,2,3, \ldots\ldots N\}$ and one base station (BS) and applying a (SIC) at the receivers. Users simultaneously receive data from the BS, under the constraint of total power. Channels are sorted as: $0 < \ |h_1\ |^2 \leq \ |h_2\ |^2 \ldots \leq \ |h_i\ |^2 \ldots\ldots \leq h_N\ |^2$

With the SC at the transmitter side (BS) SIC decoding techniques at the receiver side, PD-NOMA scheme achieves concurrent serving of all receivers by means of utilizing the entire system frequency resources to transmit data. The BS transmits a linear superposition of N users' messages by allocating β_i, a fraction of the BS power P to each user U_i, $(P_i = \beta_i P)$, where, P_i is the power allocated to U_i. On the other hand, each user decodes the signal of the weaker users at the receiver side, i.e., the signal can be decoded by U_i for each user U_m with $m\ < i$. The message for weaker users are then derived from the received signal to decode the message of user U_i, while processing the signals of the stronger users, U_m, with $m\ < i$, as interference. The received signal at user U_i can be written as:

$$y_i = h_i x + w_i \qquad (1)$$

Where, $x = \sum_{i=1}^{N} \sqrt{P\ \beta i}\ S_i$ is the superimposed PD-NOMA signal, S_i is the signal of user U_i and w_{ithe} is the additive white Gaussian noise (AWGN) of user U_i with zero mean and variance σ_n^2. If signal superposition at the BS, and SIC at U_i, are performed effectively, the data rate attainable for user U_i for 1 Hz system BW is given by:

$$R_i = log_2\ (1 + \frac{\beta i P\ |h_i\ |^2}{P\ |h_i\ |^2 \sum_{k=i+1}^{N} \beta_k + \sigma_{\ n}^{\ 2}}\ ) \qquad (2)$$

The data rate for the user U_N is denoted by the expression:

$$R_N = log_2\ \left(1 + \ \beta_N P\ |\frac{h_N\ |^2}{\sigma_{\ n}^{\ 2}}\right) \qquad (3)$$

Therefore, PD-NOMA aligns with the basic concept of SIC, where the strongest signal is decoded first. Fig. 2(a) and 2(b) illustrate the decoding process of the NOMA signal in the downlink PD-NOMA system.

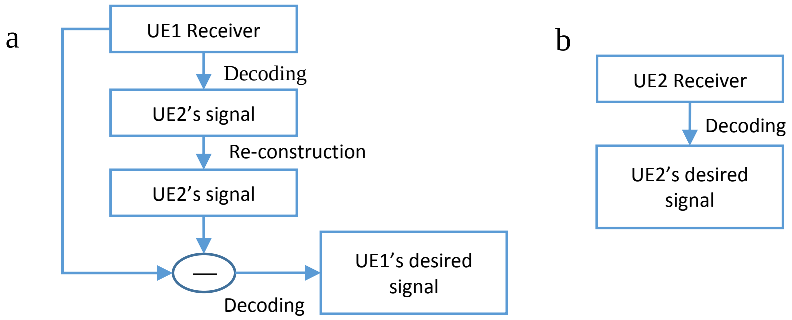

Fig. 2 - (a) UE1 Receiver Operation; (b) UE2 Receiver Operation

Let us consider the whole frequency band is simultaneously used by two users by assuming a 1Hz overall system transmission bandwidth. Owing to the fact that user 1 has a higher channel gain than user 2 it first performs SIC to decode the signal for user 1. The decoded signal is then deducted from the received signal of user 2. The resultant signal is applied in decoding the signal for user 2. Since SIC is not executed for user 1, the signal is directly decoded. Thus, the achievable data rate for users 1 and 2 are given by (4) and (5), respectively.

$$R_1 = log_2\,(1 + P_2\,|h_2|^2/\sigma_n^2) \tag{4}$$

$$R_2 = log_2\,(1 + \frac{P_1\,|h_1|^2}{P_2\,|h_1|^2+\sigma_n^2}) \tag{5}$$

Unlikely, the concept of uplink PD-NOMA is not the same as in downlink PD-NOMA. Multiple signals of different UEs are transmitted to a single receiver at BS over the same frequency resources. Users independently transmits its signal with either maximum transmit power or controlled transmit power depends on the channel gain differences among the PD-NOMA users. At the receiver side (BS), all Signals are the desired signals and each received signal experiences different channel gain. Therefore, to apply SIC and decode signals, we need to keep differences between various message signals, different from conventional transmit power control that intend to equalize the received signals powers.

With consideration of uplink PD-NOMA system with two users transmit their messages at either maximum or controlled power to a common BS over the same frequency band. Let us consider UE1 has a strong signal power P_1 and UE2 has a weaker signal powerP_2. The BS receives the superposed message signal of two users and applies SIC to decode each signal. Since the received signal from the highest channel gain user is likely the strongest at the BS; therefore, this signal is decoded first then the second user signal is decoded, i.e.; the receiver can detect the UE1 signal in the presence of interference from the UE2 signal, and then it can subtract the detected UE1signal from the received signal to detect the weaker UE2 signal without interference. Assuming that the channel is an additive white Gaussian noise (AWGN) channel of normalized bandwidth W = 1 Hz. The achievable capacity in bits per Hertz for both users can expressed as:

$$R_1 = \log_2(1 + \frac{P_1\,|h_1|^2}{P_2\,|h_1|^2+\sigma_1^2}) \tag{6}$$

$$R_2 = \log_2(1 + \frac{P_2\,|h_2|^2}{\sigma_2^2}) \tag{7}$$

2.2 PD-NOMA in Multi-Cell Environment

While most of the research works have been focused on PD-NOMA in the single cell environment, which eliminate the effect of interference from neighboring cells, little attention has been given to PD-NOMA in the multi-cell environment to verify the benefits of the technique in a real multi-cell networks setting investigating the opportunities and the challenges. As the 5G networks need to be ultra-dense, inter-cell interference (ICI) become serious obstacles to reach the efficient performance of PD-NOMA in multi-cell setting. Simple channel models are in sufficient and the capacity region schemes are not recognized. However, the achievable rate regions for the interference channels are sub-optimal. As we mentioned PD-NOMA is favourable over the OMA schemes to tackle the demands for massive connectivity and broadband services for 5G multi-cell networks by having the feature of allowing more than one user to be multiplexed on the same sub-channel [10]. The key advantage of this feature is to improve spectrum efficiency. Nevertheless, in downlink PD-NOMA protocol, users located at the cell edge are allocated more power which results in an interference to neighbouring cells. To explain this situation, a cellular system with two cells and four users is considered. Fig. 3 depicts a multi-cell PD-NOMA system comprising a two-user structure for each cell. Users 1 and 2 are served by $BS1$, whereas $BS2$ serves user 3 and 4. Here, a high interference occered between users 1 and 3, which may cause degradation in the performance of PD-NOMA. Joint pre-coding of PD-NOMA users' signals across neighboring cells is then needed to reduce the inter-cell interference. In [11], a precoding scheme with reduced complexity is proposed for PD-NOMA, the multi-cell precoder is applied to the far users, e.g. to user 1 and user 3 as shown in Fig. 3.

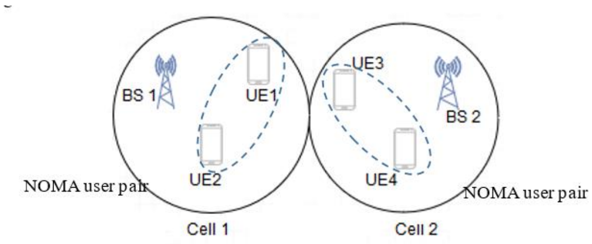

Fig. 3 – PD-NOMA in Multi-Cell Scenario

Because of inter-cell interference is a classic problem in multi-cell, most studies [11-13, 16,17] investigated the inter-cell interference apart from the intra-cell interference for downlink transmission. On the other hand, a little study explored both uplink and downlink case [16, 17]. Since NOMA shared radio resources at least a pair of users in the power domain, the effects of user pairing [11, 15, 16-18] are of interest for maximizing the system throughput. Nevertheless, little concern has been paid to the beam-forming [13, 16] and energy efficiency [14] in the PD-NOMA multi-cell system. Table 1 summarizes the limited research works focus on the multi-cell NOMA system.

Table 1 – Summary of Limited Research Work on Multi-cell NOMA

Author	**Intercell interference**	**Superposition coding**	**Resource Utilization**	**Energy Efficiency**	**Beam-forming**	**Uplink**	**Down link**	**QoS**	**User Pairing/ User clustering**
You, 2018 [11]	√		√				√		√
Nguyen, 2018 [12]		√					√	√	
Shi, 2017 [13]	√				√		√		
Chinnadurai, 2017 [14]				√			√		√
Nguyen, 2017 [15]		√						√	
Tabassum, 2017 [16]	√					√	√		√
Chinnadurai, 2017 [17]					√		√		√
Tabassum, 2017 [18]	√	√				√	√		√

3. PD-NOMA Power Control and User Selection Strategies

PD-NOMA system performance can be optimized using suitable power allocation schemes with low computational complexity to achieve high throughput of the users affected when different power levels are allocated to perform power-domain multi-user multiplexing. In [19], a Fractional transmit Power Allocation (FTPA) is proposed. In FTPA, the instantaneous channel gains of multiplexed messages are considered and power is divided to the users proportional to their path-loss raised to the power α FTPA to maximize the performance metric target. An exhaustive user selection is avoided by proposing a predefined user grouping grounded on channel gains and fixed per-group power allocation (FPA) to facilitate the achievement of a considerable value of PD-NOMA gains with less complexity.

An iterative sub-optimal power allocation algorithm is another low complexity method based on Difference of Convex (DC) programming [20]. In this method, the utility function of optimal power allocation is broken down into difference convex functions, which is then iteratively solved with a successive convex approximation to achieve an efficient sub-optimal solution. Similar to FTPA and FPA, a tree-based search and reversed SIC order is a sub-optimal reduced complexity method from weighted sum rate maximization perspective as user weights have not been considered during power allocation among the multiplexed users [21].

For the basic concept of DL-PD-NOMA system, the authors in [22-24] propose power domain user multiplexing at the BSs and SIC-based signal reception at UEs. The practical consideration and implementation challenges of PD-NOMA systems are discussed in [25]. The advantages of NOMA over OMA are confirmed by the system-level and link-level simulations in [26] by comparing overall system throughput as well as individual users' throughputs.

Taking static power allocation into account, closed-form expressions for ergodic sum-rate and outage probability are derived for two-user NOMA system [27]. Moreover, the impact of user pairing in two-user PD-NOAM system is studied in [28] proposing a fixed and opportunistic user pairing schemes by statically allocating transmission powers among users. Considering perfect channel state information (CSI) feedback as well as average CSI feedback, the effect of power allocation on the fairness of DL/PD-NOMA is investigated in [29]. The cooperative PD-NOMA system is examined in [30]. In [31], a test-bed for a two-user PD-NOMA system is presented. the experiments are performed by setting 5:4 MHz bandwidth for PD-NOMA users compared with those for a two-user OMA system where each user has a transmission bandwidth of 2:7 MHz, the results shows the significance performance enhancement of PD-NOMA compare with OMA in terms of aggregate and individual users' throughputs. Continuous attempts to examine the PD-NOMA systems and user pairing are revealed in the literature. Table 2 shows some works proposed to investigate power allocation and user pairing schemes.

On the other hand, PD-NOMA in uplink transmissions is investigated in [32] where power multiplexing is perform at UE's transmitter and minimum mean squared error (MMSE)- based SIC decoding is utilized at BS receiver. A problem of joint sub-channel and power allocation is studied in [33], where a sub-optimal solution is proposed to maximize the sum-rate of a PD-NOMA cluster. The authors in [34] derived a closed-form solutions for sum-throughput and outage probability for two-user uplink PD-NOMA system by assuming static powers for the users. The results showed the importance of proper selection of target data rate for each NOMA user to avoid user outage. This conclusion is also drawn in [28] for downlink NOMA. In a separate work, [35] design a robust user scheduling algorithm for uplink NOMA with SC-FDMA. Here, the distinct channel gains of different users are exploited to obtain efficient user grouping.

Table 2 – Proposed Solution to investigate Power Allocation and User Pairing Scheme

Author /Study	Objective Function	Optimization Problem Solution	Advantage of Proposed Solution
Wang & Chen, 2016, [36].	Maximizing the sum rate capacity.	• Karush-Kuhn-Tucker (KKT) conditions are developed: • Schemes proposed are applicable to both SISO and MIMO scenarios.	• Less computational complexity • The method is applicable to the general multiuser case.
Choi, 2016, [37].	Maximize Sum Rate. Maximize the minimum rate	Proportional fairness scheduling (PFS). PD-NOMA with two users under two different criteria; the maximum of the sum rate and the maximum of the minimum rate.	The proposed scheme can provide; proportional fairness and small variation of transmission rates.
Xunan Li, 2016, [38].	Minimize the total transmit power.	A heuristic (sub-optimal) algorithm is developed.	An algorithm achieved optimal solution and showed advantages over prevalent OMA & static NOMA schemes.
Zheng Yang, 2016, [39].	Minimizing the outage probability.	The exact expressions are derived for the outage probabilities.	Good trade-off between the user's individual rates in Hybrid-PD-NOMA compared to Fixed-PD-NOMAD and cognitive-radio PD-NOMA.
Hojeij et al. 2015, [40].	"Minimizing spectrum usage" Minimized the amount of bandwidth (sub-bands) provided to each user to satisfy the requested data rate.	A hybrid solution consists of : • Dynamic switching from NOMA to Orthogonal Signaling (OS). • Power allocation scheme based on water-filling.	The proposed algorithm achieved two goals: 1. Reduce the amount of used bandwidth. 2. Improve capacity

4. MIMO and NOMA Combination

The main idea behind the combination of MIMO NOMA is when NOMA is extended in such a way that the base station and the user equipment's are equipped with many antennas. The antennas at the base station for downlink transmissions can be used either for beam-forming to enhance the received SNR or for spatial multiplexing to enhance the throughput [41, 42]. With beam-forming (NOMA-BF), the spectral efficiency is enhanced when the power domain and the spatial domain are exploited by NOMA.

The extra dimension MIMO provides improves system performance and enhances the spectral efficiency. As illustrated in Fig.4, multiple antennas at a base-station are forming different beams in the spatial domain where basic NOMA operates each beam. The spatial filtering suppresses the inter-beam interference at the receiver side in such a way that the intra-beam SIC removes the inter-user interference.

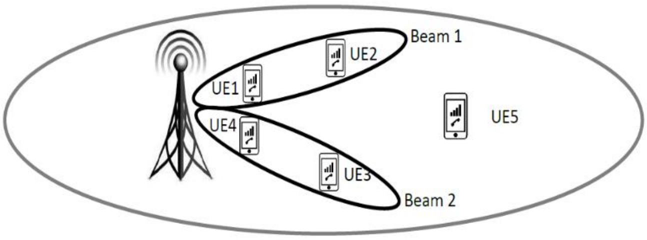

Fig. 4 – NOMA/MIMO System

The effect of error propagation of SIC and user velocity on NOMA performance for multiple-input multiple output (MIMO) systems is explored in the literature confirmed that NOMA outperforms conventional orthogonal multiple access even in the worst error propagation scenario can result in performance gains for different user mobility [43]. Various algorithmic frameworks for optimizing the design of beam forming in the NOMA transmission system is proposed by considering the scenario in which each user has a single antenna. Moreover, the antenna selection and user scheduling problems in massive MIMO-NOMA system were investigated in [44], an efficient antenna selection and user scheduling algorithm were developed by first considering a basic single-band two-user setting for which they raise an efficient search algorithm for antenna selection. The sum rate is used as an objective function in the formulation of various optimization problems in MIMO-NOMA scenarios [45]. MIMO-NOMA system with random beam-forming was proposed in [46]. The base station with multiple antennas randomly form the transmit beams and the users falling in these beams will be served in an opportunistic manner.

5. NOMA Challenges and Future Research

Despite the vast literature in NOMA system, there are still some challenges and future research needs to be considered. Some of the challenges include:

5.1 Resource Allocation

Meeting the 5G requirements of very high data rates coupled with low latency so as to cover a diverse range of traffic requirements is a difficult one mainly due to the limited resources available as mentioned earlier. Based on this premise, it becomes quite apparent that the key to effective utilization and allocation lies on inventing new techniques of Wireless resource management. As a sequence of processes that need to take place in order to determine the timing and quota of resource allocation to users, wireless resource management takes into factor the specific kind of resource. According to Shannon's Information Capacity theorem, spectrum is one of the wireless resources to look into in this particular scenario. As part of the Wireless resource management process in a communication system, the total bandwidth is first broken up into sub-bands. Each set of sub-band is assigned to different user or group of users (as in the case of NOMA). As discussed in section 3, the resource allocation in terms of user-pairing and optimal power allocation between users in PD-NOMA is wholly dependent on the availability of efficient algorithm(s) to provide the most optimal performance with minimal resource requirement.

5.2 Transmission Distortion

Transmission of data, for instance, audio and video packets, is, on a general note, considered as being lossy. The transmitted data progressively experience distortion in the process of being propagated to the recipient. In an effort to address this issue, considerable research has been conducted in developing theoretical models aimed at encapsulating the problem of source fidelity over fading channels till date. Different source code and channel code framed to reduce this distortion effect [47, 48]. However, this gives rise to a variety of conflicting trade-off situations between distortion, cost, and complexity due to source coding and channel code diversity in the process. The capacity of the information and the distortion depends on the outage probability. Based on this fact, the outage probability that maximizes outage rate may not necessarily give the minimum distortion, especially in the case of power domain utilization. Therefore, research efforts can be initiated to determine the optimal outage probability for PD-NOMA system to generate the maximum outage rate with acceptable levels of distortion.

5.3 SIC Implementation

SIC is a core part of the PD-NOMA scheme, which, based on research outcomes, is known to achieve an optimal capacity region for downlink as well as uplink transmission (in a single-cell network) and the best-known rate region in multi-cell settings. Unfortunately, SIC is constrained by many issues, as described below.

- SIC requires the decoding of each user's information in order of priority determined by the SIC decoding order. This results in the signal decoding complexity scaling with as total user count in the particular cell grows. To address this complex issue, we can split the total amount of users into multiple groups and encode/decode on each group basis. By doing so, the amount of complexity would be brought down to a reasonable level enough to be handled properly.
- Error propagation refers to a scenario where an error happens in decoding a specific user's signal, thereby causing the error to cascade down in the SIC decoding order to other users who will be affected and their signal decoding likely to be error-prone. This difficult issue can be addressed through the utilization of stronger codes with limited number of users.

Another topic of future research is evaluating the performance of PD-NOMA in the presence of beam-formers and MU-MIMO. NOMA is expected to yield more gains when co-existing with MU-MIMO. In this case, the user multiplexing in a power domain using NOMA is orthogonal to the user multiplexing in the spatial domain using MU-MIMO. The co-scheduled UEs in NOMA are assumed to use the same beam-former so that the cell-centre UE can decode the transmissions to the cell-edge UE. Another future topic can be the performance analysis of a cooperative NOMA scheme, especially in the existing dynamic interfering environment.

The combination of PD-NOMA with other multiple access schemes, including newly developed 5G multiple access techniques are also worth studying. Furthermore, since user pairing/clustering is believed to reduce system complexity, new low-complexity algorithms need to be developed in order to realize optimal user clustering.

6. Conclusion

In this paper, the concept of PD-NOMA is introduced as a potential multiple access candidate for next generation radio access technology 5G. The main idea of PD-NOMA is that multiple users are served simultaneously over the same radio resources with minimal inter-user interference involved. Relying on power domain, NOMA contributes to better spectral efficiency by allowing each user access to all subcarriers channels. The PDM-NOMA is able to perform (SIC) at users with better channel conditions. Power domain is not utilized in the previous systems which make NOMA as a multiplexing scheme suitable for 5G mobile and wireless communications.

In a single cell scenario, the transmitter and receiver antennas are assumed to explain the concept of downlink PD-NOMA. In the multi-cell scenario, PD-NOMA allows more than one user to be multiplexed on the same sub-channel in order to improve spectrum efficiency. The performance of PD-NOMA systems can be optimized by using less complicated power allocation schemes. The throughput of other users achieved is affected when power is allocated to one user due to power-domain multi-user multiplexing.

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