α-Fairness User Pairing for Downlink NOMA Systems with Imperfect Successive Interference Cancellation

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Abstract—Non-orthogonal multiple access (NOMA) is considered as one of the predominant multiple access technique for the next-generation cellular networks. We consider a 2-user pair downlink NOMA system with imperfect successive interference cancellation (SIC). We consider bounds on the power allocation factors and then formulate the power allocation as an optimization problem to achieve α-Fairness among the paired users. We show that α-Fairness based power allocation factor coincides with lower bound on power allocation factor in case of perfect SIC and α > 2. Further, as long as the proposed criterion is satisfied, it converges to the upper bound with increasing imperfection in SIC. Similarly, we show that, for 0 < α < 1, the optimal power allocation factor coincides with the derived lower bound on power allocation. Based on these observations, we then propose a low complexity sub-optimal algorithm. Through extensive simulations, we analyse the performance of the proposed algorithm and compare the performance against the state-of-the-art algorithms. We show that even though Near-Far based pairing achieves better fairness than the proposed algorithms, it fails to achieve rates equivalent to its orthogonal multiple access counterparts with increasing imperfections in SIC. Further, we show that the proposed optimal and sub-optimal algorithms achieve significant improvements in terms of fairness as compared to the state-of-the-art algorithms.

Index Terms—Fairness, imperfect successive interference cancellation (SIC), non-orthogonal multiple access (NOMA), power allocation, spectral efficiency.

I. INTRODUCTION

Non-orthogonal multiple access (NOMA) is a promising technology that has capability to fulfill diverse requirements of next generation multiple access (NGMA) [1]. It achieves significant data rates for a large number of users and efficient utilization of the spectrum, thus, becoming a key spectrally efficient technology. There exists different approaches for NOMA, which can broadly be classified into two categories as Power-Domain NOMA and Code-Domain NOMA. In Power Domain-NOMA, the base station allocates different power allocation factors to the multiplexed users, whereas, in the Code-Domain NOMA, the users are multiplexed in the code domain [2]. The main idea behind PD-NOMA is allowing multiple users to access the same resource block but with varying power levels. The two key principles of NOMA are superposition coding and successive interference cancellation (SIC). The transmitter superimposes the information related to multiple users and transmits in a single resource block (same space-time-frequency resource), i.e., the transmitter performs superposition coding. At the higher channel gain user, superposed information needs to be decoded and SIC serves this purpose [3], whereas, the user with lower channel gain decodes its information by considering the information related to higher channel gain user as noise.

NOMA can combine with diverse technologies and help in increasing the capacity of the system, providing user fairness and achieving spectral efficiency [4]. Most of the researchers from academia, industry as well as policy making are actively investigating NOMA. However, there are many design and implementation issues that needs to be addressed. User pairing and power allocation strategies have always been crucial to achieve better NOMA performance. Given a NOMA user pair, the authors in [3] validated that the individual user rates exceed its corresponding orthogonal multiple access (OMA) rates. This is always true for perfect SIC case, wherein, we assume that the higher channel gain user decodes its information perfectly. However, in a practical scenario, there is always some imperfection associated with SIC due to hardware impairments or implementation issues such as complexity scaling and error propagation [5]. This phenomenon impacts the achievable rate of the user with higher channel gain in a NOMA pair, directly affecting the overall throughput of the system. Hence, the network operators have to consider the impact of imperfections in SIC while performing scheduling and power allocation to realize the true benefits of NOMA.

Some works in the existing literature have considered the impact of imperfection in SIC [5], [6]. However, this is the first work that consider the imperfection in SIC while performing α-Fairness based power allocation for a 2-user pair in the downlink NOMA system. In view of the aforementioned details, we present the following key contributions in this paper.

1. We present a detailed analysis on α-Fairness among the 2-user pair in a practical NOMA system with imperfect SIC.
2. We formulate maximizing the utility function as an optimization problem for the downlink NOMA system in the presence of imperfect SIC.
3. We propose a low-complexity sub-optimal algorithm for α-Fairness-based power allocation, performing similar to optimal algorithm based on the optimization problem formulated.
4. We perform extensive numerical evaluations and show that the proposed algorithms significantly outperform the state-of-the-art algorithms.
The organization of the paper is as follows. In Section II, we present relevant related works in the literature. The system model is explained in Section III along with brief introduction on the upper and lower bounds on power allocation factors. The $\alpha$-Fairness based optimization problem is formulated in Section IV, with explanation of the optimal and sub-optimal algorithm. Numerical results are presented in Section V with detailed explanation of plots generated. Section VI comprises of some concluding remarks and the scope of future works.

II. RELATED WORKS

In this section, we will discuss a few relevant fairness based formulations and proposed schemes for NOMA systems. Most of the state-of-the-art techniques proposed for user pairing and power allocation focus on improving the overall system throughput at the expense of fairness among the paired users. Moreover, the existing works which considered fairness such as [7]–[9], have not analyzed or studied the impact of imperfection in SIC. In [7], authors have implemented a lossless NOMA without SIC and proved the conditional achievable sum-rate given channel gain realizations in the conventional NOMA scheme without SIC, without loss, over the power allocation range of user-fairness. The authors in [8] have proposed a joint user pairing and power allocation algorithm in the NOMA uplink communication systems, aiming at improving the proportional fairness of the users. The authors in [9] have proposed a new resource allocation scheme for a downlink OFDMA-based NOMA system to maximize the sum capacity performance under a general proportional user fairness constraint. A spectrum resource and power allocation algorithm with adaptive proportional fair user pairing has been proposed to convert the formulated optimization problem into user pairing, sub-channel, and power allocation in [10].

Some authors have also considered max-min fairness apart from the proportional fairness based user pairing and power allocation schemes for NOMA as discussed in [8]–[10]. Authors in [11] proposed optimal power allocation rules in a variety of problem settings: 1) max-min fairness, 2) sum-rate maximization with a minimum data rate constraint, and 3) weighted sum-rate maximization for improving data rates of cell-edge users. The resource allocation problem for NOMA-enabled V2X communications has been investigated in [12], where weighted max-min rate fairness is applied to achieve user fairness and the different requirements of cellular users.

In [13], $\alpha$-Fairness based power allocation schemes for sum throughput and ergodic rate maximization problems in a downlink NOMA system have been analyzed. The resource allocation fairness of the NOMA and OMA schemes have been investigated in [14], wherein the fundamental reason of NOMA being more fair than OMA in asymmetric multiuser channels has been analyzed. The authors in [15] have maximized the average sum rate ensuring a minimum average rate for each user by optimally adapting the power and rate allocations to varying fading states. However, none of the works have considered the fairness among the paired users and the trade-off with imperfect SIC to achieve such fairness for a downlink NOMA system.

III. SYSTEM MODEL

Without loss of generality, we consider a 5G cellular network as shown in Fig. 1 and focus on the downlink NOMA 2-user pairing scheme. In a typical OMA system, the downlink signal-to-interference-plus-noise ratio (SINR) from the transmitter (i.e., the base station) to a receiver (user $u$), on a subchannel, is formulated as

$$\gamma_u = \frac{P_t |h_u|^2}{\sigma^2 + I},$$

where $P_t$ is the transmitted power, $h_u$ is the channel gain of user $u$, $\sigma^2$ is the noise power, and $I$ is the interference received on the subchannel allocated to the user $u$ from nearby base stations. The normalized downlink rate for such a user in an OMA based log rate (LR) model is

$$R_u^{\text{OMA}} = \frac{1}{2} \log_2 \left(1 + \gamma_u\right),$$

where the factor $1/2$ is considered owing to the loss in multiplexing in OMA system.

A. NOMA Rate Formulation

Consider a strong user $U_s$ and weak user $U_w$ NOMA pair, such that the relation between their channel gains from a particular base station is $|h_s|^2 > |h_w|^2$. For the NOMA LR formulation, let us assume the fraction of power allocated to user $U_s$ is $\delta_s$ and $U_w$ is $1 - \delta_s$. Let $\beta \in [0, 1]$ be the imperfection in SIC associated with the strong user resulting from implementation issues such as complexity scaling and error propagation [5]. The SINR of the NOMA user pair, i.e., $\hat{\gamma}_s$ and $\hat{\gamma}_w$, can be, respectively, expressed as [5]

$$\hat{\gamma}_s = \frac{\delta_s P_t |h_s|^2}{\sigma^2 + I + \beta (1 - \delta_s) P_t |h_s|^2}$$

and

$$\hat{\gamma}_w = \frac{(1 - \delta_s) P_t |h_w|^2}{\sigma^2 + I + \delta_s P_t |h_w|^2},$$

where $\beta = 0$ implies perfect SIC case, i.e., the strong user is completely able to remove the interference from the weak.
user. Following similar formulations as in [6], we reformulate (3) using (2) as follows
\[
\hat{\gamma}_s = \frac{\delta_s \gamma_s}{1 + \beta (1 - \delta_s) \gamma_s} \quad \text{and} \quad \hat{\gamma}_w = \frac{(1 - \delta_s) \gamma_w}{1 + \delta_s \gamma_w}.
\]
(4)

Further, the NOMA rates of the user pair, i.e., \(R_{s}^{\text{NOMA}}\) and \(R_{w}^{\text{NOMA}}\), are respectively given by
\[
R_{s}^{\text{NOMA}} = \log_2 (1 + \hat{\gamma}_s) \quad \text{and} \quad R_{w}^{\text{NOMA}} = \log_2 (1 + \hat{\gamma}_w).
\]
(5)

**B. Bounds on Power Allocation Factor**

We consider the upper and lower bounds on the power allocation factor \(\delta_s\) from our previous work [6]. As shown in [6], solving \(R_{w}^{\text{NOMA}} > R_{w}^{\text{OMA}}\) results in (6), which ensures weak user NOMA rate is greater than its OMA rate. Similarly, solving \(R_{s}^{\text{NOMA}} > R_{s}^{\text{OMA}}\) results in \(\delta_{ub}\) (7), such that strong user NOMA rate is greater than its OMA counterpart.

\[
\delta_{ub} = \frac{1}{\gamma_w} \left( \sqrt{1 + \gamma_w} - 1 \right), \quad (6)
\]
\[
\delta_{lb} = \frac{(1 + \beta \gamma_s)(\sqrt{1 + \gamma_s} - 1)}{\gamma_s(1 + \beta \sqrt{1 + \gamma_s} - \beta)}.
\]
(7)

Considering individual rates with NOMA to be better than the corresponding OMA rates as shown in (5) and solving for achievable sum-rate with NOMA to be better than achievable sum-rate with OMA, the minimum SIR difference (MSD) criterion for two users to be paired is formulated as [6]
\[
\Delta_{\text{MSD}} = \gamma_s - \frac{(\sqrt{1 + \gamma_w} - 1) (\sqrt{1 + \gamma_s \sqrt{1 + \gamma_w} + 1})}{\sqrt{1 + \gamma_w}}.
\]
(8)

For a given pair of users, if \(\gamma_s - \gamma_w > \Delta_{\text{MSD}}\), then we will be able to find a \(\delta_s\) between \(\delta_{lb}\) and \(\delta_{ub}\) such that individual NOMA rates exceed their OMA counterparts, provided \(\delta_s < \beta^*\). Here, \(\beta\) is the imperfection in SIC and \(\beta^*\) is the upper bound on the same, formulated as
\[
\beta < \frac{\gamma_w - \gamma_s + \gamma_s \sqrt{1 + \gamma_w} - \gamma_w \sqrt{1 + \gamma_s}}{\gamma_s (\sqrt{1 + \gamma_s - 1}) (\sqrt{1 + \gamma_w} - \sqrt{1 + \gamma_w} + 1)} \triangleq \beta^*.
\]
(9)

Readers unfamiliar with the MSD criterion and the bounds on the imperfect SIC are suggested to read our previous work which has detailed explanation for the same [6].

**C. \(\alpha\)-Fair Scheduler**

The utility function for an \(\alpha\)-Fair scheduler with the variable \(x\) is expressed as [16]
\[
U_\alpha(x) = \begin{cases} 
\frac{x^{1-\alpha}}{1-\alpha} & \text{if } \alpha > 0, \alpha \neq 1, \\
\log(x) & \text{if } \alpha = 1.
\end{cases}
\]
(10)

The performance metric to measure the system performance of NOMA user rates, i.e., \(\alpha\)-Fair throughput is [16]
\[
T_\alpha(x) = \begin{cases} 
\left( \frac{1}{\beta} (R_{s}^{\text{NOMA}})^{1-\alpha} + (R_{w}^{\text{NOMA}})^{1-\alpha} \right)^{1/(1-\alpha)} & \text{if } \alpha > 0, \alpha \neq 1, \\
(R_{s}^{\text{NOMA}} R_{w}^{\text{NOMA}})^{1/2} & \text{if } \alpha = 1.
\end{cases}
\]
(11)

Next, we present the proposed algorithms.

**IV. PROPOSED ALGORITHMS**

In this section, we initially formulate the power allocation for the paired users as an optimization problem and then present a sub-optimal algorithm that achieves close to optimal performance.

**A. Optimal Algorithm**

Given the rates of strong and weak user as in (3), we maximize the utility function presented in (10) while ensuring a minimum of OMA rates for each paired user. Thus, we formulate the optimization problem as follows

\[
P_1 : \max_{\delta_s} \left( U_\alpha(R_{s}^{\text{NOMA}}) + U_\alpha(R_{w}^{\text{NOMA}}) \right)
\]
(12)

subject to
\[
R_{s}^{\text{NOMA}} > R_{s}^{\text{OMA}}, \quad (13)
\]
\[
R_{w}^{\text{NOMA}} > R_{w}^{\text{OMA}}, \quad (14)
\]
\[
\delta_s < \delta_{ub}, \quad (15)
\]
\[
\delta_s > \delta_{lb}, \quad (16)
\]
\[
0 < \delta_s, \delta_w < 1, \quad (17)
\]
\[
0 \leq \delta_s + \delta_w \leq 1, \quad (18)
\]

where (12) is the overall objective function for maximizing the \(\alpha\)-fairness among the NOMA pair under consideration over \(\delta_s\). The constraints in (13) and (14) ensure that the strong and weak user NOMA rates exceed their OMA counterparts. We need to pick \(\delta_s\) between the upper and lower bounds as in [6], and hence, we consider (15) and (16). The constraint in (17) ensures that the fraction of power allocated to strong and weak user lie between 0 and 1. Moreover, in downlink NOMA, their sum is 1, thus, we have (18). The given problem \(P_1\) in (12) is a non-linear programming problem (NLP), which is difficult to solve with first order differentiation. Hence, next, we present a low-complexity sub-optimal algorithm that can be realized in practical implementation and achieves close to optimal performance.

**B. Sub-optimal Algorithm**

Considering the strong user rate is greater than the weak user rate and \(\alpha < 1\), because of the positive exponentials in the utility function, the optimization formulation in (12) is significantly dependent on \(R_{s}^{\text{NOMA}}\) in perfect SIC case. Further, a smaller increase in \(\delta_s\) significantly increases the \(R_{s}^{\text{NOMA}}\) and slightly decreases the \(R_{w}^{\text{NOMA}}\). Hence, larger the value of \(\delta_s\), greater will be the value of the objective function in (12). Thus, for \(0 < \alpha \leq 1\), we choose \(\delta_s = \delta_{ub}\). Similarly, for \(\alpha > 1\), because of the negative exponentials in the utility functions, the optimization problem formulated in (12) is significantly dependent on \(R_{w}^{\text{NOMA}}\), and hence, the smaller the value of \(\delta_s\), the greater will be the value of the objective function in (12). Thus, for \(\alpha > 1\), we choose \(\delta_s = \delta_{lb}\). However, with an increase in the \(\beta\) value, the \(R_{w}^{\text{NOMA}}\) value decreases. Hence, for larger \(\beta\), to ensure minimum OMA rates for the strong user, we need to choose \(\delta_s = \delta_{ub}\). Note that we consider the users for NOMA pairing only when they meet the minimum SINR criterion presented in (8). Otherwise, we consider them for OMA.
Algorithm 1 Proposed Algorithms.

INPUTS : $\gamma_s, \gamma_w, \beta_s, \alpha, \tau$
OUTPUTS : $\delta_s$

Optimal Algorithm:
1. if $\bar{\gamma}_s - \bar{\gamma}_w > \Delta_{MSD}^*$ and $\beta_s < \beta^*$
2. Solve $P1$ to get $\delta_s$
3. Pair $\bar{\gamma}_s, \bar{\gamma}_w$ using the resultant $\delta_s$ from $P1$
4. else
5. Consider $\bar{\gamma}_s, \bar{\gamma}_w$ as OMA users.
6. end

Sub-Optimal Algorithm:
1. if $\bar{\gamma}_s - \bar{\gamma}_w > \Delta_{MSD}^*$
2. if $\left( \beta_s/\beta^* < \tau \right)$
3. if $\left( \alpha > 1 \right)$
4. $\delta_s = \delta_{lb}$
5. else if $\left( 0 < \alpha \leq 1 \right)$
6. $\delta_s = \delta_{ub}$
7. end
8. else
9. if $\left( \alpha > 1 \right)$
10. $\delta_s = \delta_{ub}$
11. else if $\left( 0 < \alpha \leq 1 \right)$
12. $\delta_s = \delta_{ub}$
13. end
14. end
15. else
16. Consider $\bar{\gamma}_s, \bar{\gamma}_w$ as OMA users.
17. end

For a given NOMA pair, we denote the worst case imperfection in SIC possible as $\beta_s$ and the maximum permissible imperfection in SIC as $\beta^*$ (obtained from (9)). In the sub-optimal algorithm, we consider $\beta_s$ to be a smaller value when it satisfies $(\beta_s/\beta^*) < \tau$. Otherwise, we consider $\beta_s$ to be a larger value and closer to $\beta^*$. Then, we allocate the power to the users based on the earlier explanation. We have summarized the entire procedure for optimal and sub-optimal power allocation in Algorithm 1.

C. Baseline Algorithms considered for Evaluation

1) Near-Far (NF): For comparison with the proposed $\alpha$-Fairness-based power allocation, we consider the NF algorithm presented in [17]. The users are initially sorted in decreasing order of their channel gains. Then, two users are picked sequentially one from the beginning and the other from the end of the sorted user list and paired together for NOMA transmission. The algorithm achieves significant improvement in the network throughput because of the sorting. However, the algorithm does not consider the practical imperfections in SIC while pairing users, and hence, the performance degrades with the increase in the imperfections in SIC.

2) OMA: For the same set of users, we evaluate the network performance with OMA. For this scenario, we consider the formulations presented in (1)-(2).

3) Derived bounds: We also evaluate the network performance by considering the power allocation factors equal to the derived upper and lower bounds formulated in (6)-(7). Further, in this evaluation, we also consider the MSD formulated in (8) and the derived bounds on the imperfection in SIC presented in (9). Next, we present the detailed simulation set up and discuss the numerical results.

V. RESULTS AND DISCUSSION

We consider Poisson point distributed base stations and user positions with densities 25 BS/km$^2$ and 120 users/km$^2$, respectively, as in [18]. We perform Monte Carlo simulations for an urban cellular environment pathloss model [19] considering Rayleigh fading model (scaling parameter = 1) and omnidirectional antennas. The user association to a particular BS is based on the maximum SINR received by all the BSs. We study the variation in the fraction of power allocated for different values of $\alpha$ by considering both perfect and imperfect SIC cases. We compare the performance of optimal and sub-optimal algorithms (assuming $\tau = 0.5$) presented in $P1$ with...
Remark 1: In our proposed sub-optimal algorithm:

- The fairness based power allocation factor from the optimization problem, i.e., $\delta_f$ is equivalent to the lower bound in case of perfect SIC and higher $\alpha$. This $\delta_f$ tends towards the upper bound with increase in imperfection in SIC as observed for $\beta = [0.03, 0.08]$ in Fig. 2. Further, it is equivalent to upper bound, i.e., $\delta_{ub}$ when $\beta = \beta^*$ for all values of $\alpha$. Thus, we note the following important remarks observed from Fig. 2 which are aligned with the formulations in our proposed sub-optimal algorithm:

Remark 1: Given a perfect SIC NOMA system i.e., $\beta = 0$, the fairness based power allocation $\delta_f$ is equivalent to the lower bound $\delta_{lb} \forall \alpha > 2$.

Remark 2: For $0 < \alpha < 1$, the fairness based power allocation $\delta_f$ is equivalent to the upper bound $\delta_{ub}, \forall \beta < \beta^*$.

Fig. 3 illustrates the variation of $\delta_f$ with imperfection in SIC for different values of $\alpha$, i.e., $\alpha = [0.3, 0.6, 1, 25, 35]$. For $0 < \alpha < 1$, the $\alpha$-Fairness based power allocation is equivalent to the upper bound, for $\beta < \beta^*$. Further, for $\beta = 0$, we observe that the $\alpha$-Fairness based power allocation is equivalent to lower bound $\delta_{lb}$ for any $\alpha > 1$. However, for higher values of $\alpha$ and $\beta < \beta^*$, the resultant $\delta_s$ from the optimal algorithm in PI always lies between the upper and lower bounds on $\delta_s$. Further, with increase in $\beta$, the value moves away from lower bound and converges with the upper bound as shown in Fig. 3. This illustration gives us another important remark which is aligned with our formulation in the sub-optimal algorithm:

Remark 3: Given an imperfect SIC NOMA system where $\beta = \beta^*$, the fairness based power allocation $\delta_f$ is equivalent to the upper bound $\delta_{ub}$, for any $\alpha$.

Fig. 4a and Fig. 4b illustrate the variation of $T_\alpha$ with respect to different values of $\alpha$, i.e., $[1, 2, 5, 20]$ for $\beta = 0.01$ and $\beta = 0.06$, respectively. We consider $\tau = 0.5$ for all sub-optimal related simulation results. We observe that NF-based scheme performs better than all strategies in both the figures, however, the strong user fails in achieving its individual OMA rate as is shown in Fig. 5a and Fig. 5b. Further, it is evident from Fig. 4a and Fig. 4b that the performance of proposed suboptimal algorithm is almost equal to the optimal algorithm and is better than the performance of OMA. A peculiar remark in the performance metric plot is that the optimal and sub-optimal algorithm’s performance always lies between the performance of lower bound and upper bound based power allocations. However, the strong user rate is unable to achieve at least its OMA rate not only in case of NF-based pairing, but also in lower bound based power allocation.

The variation of $T_\alpha$ with respect to imperfection in SIC $\beta$ for $\alpha = 1$ is presented in Fig. 4c. We observe that with increase in imperfection in SIC, given $\alpha = 1$, the parameter metric corresponding to $\alpha$-Fairness scheduler outperforms all other strategies for lower values of $\beta$ and converges with OMA for higher values of $\beta$. The performance of NF-based pairing strategy decreases beyond OMA with increasing $\beta$. This is because, given $\alpha = 1$, we are computing product of strong and weak user rates and with increase in $\beta$, the rate of strong user decreases gradually in NF pairing.

Fig. 5a and Fig. 5b illustrate the mean user rate (MUR) comparison for varying $\alpha$, given the imperfection in SIC is $\beta = 0.01$ and $\beta = 0.06$, respectively. We observe that $\alpha_{ub}$ based power allocation results in better strong user mean rates and the weak user achieves OMA equivalent mean user rates, nevertheless, the performance in terms of fairness is poor as observed in Fig. 4a and Fig. 4b. The $\alpha_{ub}$ based power allocation scheme achieves better weak user mean rates but the strong user mean rates are far below the OMA based mean user rates because of the imperfection in SIC. Thus, even though the $T_\alpha$ values of $\alpha_{ub}$, based power allocation scheme exceeds the optimal and sub-optimal values as in Fig. 4a and Fig. 4b, it fails to achieve individual OMA rates as the imperfection in SIC deteriorates the performance of the strong user. The same is the case with NF-based pairing strategy. Even though NF based pairing strategy achieves better $T_\alpha$ values in Fig. 4a and Fig. 4b, it is evident from Fig. 5a and Fig. 5b that the strong user is unable to achieve at least OMA rates. Lastly, the optimal and sub-optimal algorithm based resultant MURs are...
In NF-based pairing, it is better than OMA, strongly user mean rates for different values of \( \beta \) and then converges with OMA, while the weak user mean rate is less than OMA for certain values of \( \beta \). However, they converge with OMA for higher values of \( \beta \).

VI. CONCLUSION

We have presented a detailed analysis on \( \alpha \)-Fairness among the 2-user pair for downlink NOMA system in the presence of imperfection in SIC. We have formulated the power allocation for the paired users as an optimization problem that achieves \( \alpha \)-Fairness and ensures minimum of OMA rates for the paired users. Further, we have also proposed a low-complexity suboptimal algorithm that achieves close to optimal performance. We have performed extensive simulations and compared the performance of the proposed algorithms against the state-of-the-art algorithms. Both the proposed optimal and suboptimal algorithms achieve significant improvements in the network performance. In the future, we plan to implement and evaluate the proposed algorithms in the hardware testbeds.

REFERENCES

[1] Z. Ding et al., “Application of Non-Orthogonal Multiple Access in LTE and 5G Networks,” IEEE Commun. Mag., vol. 55, no. 2, pp. 185–191, 2017.

[2] L. Dai et al., “A Survey of Non-Orthogonal Multiple Access for 5G,” IEEE Commun. Surveys Tuts., vol. 20, no. 3, pp. 2294–2323, 2018.

[3] Y. Saito et al., “Non-Orthogonal Multiple Access for Cellular Future Radio Access,” in Proc. IEEE 77th VTC Spring, Dresden, Germany, 2013, pp. 1–5.

[4] M. Varzi et al., “Interplay between NOMA and other Emerging Technologies: A Survey,” IEEE Trans. Cogn. Commun. Netw., vol. 5, no. 4, pp. 900–919, 2019.

[5] D. Do et al., “Impacts of Imperfect SIC and Imperfect Hardware in Performance Analysis on AF Non-orthogonal multiple access Network,” Telecommun. Syst., vol. 72, pp. 579–593, 2019.

[6] N. S. Mouni et al., “Adaptive User Pairing for NOMA Systems With Imperfect SIC,” IEEE Wireless Commun. Lett., vol. 10, no. 7, pp. 1547–1551, 2021.

[7] K. Chung, “Correlated Superposition Coding: Lossless Two-User NOMA Implementation Without SIC Under User-Fairness,” IEEE Wireless Commun. Lett., vol. 10, no. 9, pp. 1999–2003, 2021.

[8] L. Chen et al., “Proportional Fairness-Based User Pairing and Power Allocation Algorithm for Non-Orthogonal Multiple Access System,” IEEE Access, vol. 7, pp. 19 602–19 615, 2019.

[9] C.-L. Wang and C.-W. Hung, “Proportional-Fairness Resource Allocation for a Downlink Multicarrier NOMA System,” in Proc. 14th ICSPCS, Adelaide, SA, Australia, 2020, pp. 1–6.

[10] K. Long et al., “Spectrum Resource and Power Allocation With Adaptive Proportional Fair User Pairing For NOMA Systems,” IEEE Access, vol. 7, pp. 80 043–80 057, 2019.

[11] D. Kim and M. Choi, “Non-Orthogonal Multiple Access in Distributed Antenna Systems for Max-Min Fairness and Max-Sum-Rate,” IEEE Access, vol. 9, pp. 69 467–69 480, 2021.

[12] H. Zheng et al., “Joint Resource Allocation With Weighted Max-Min Fairness for NOMA-Enabled V2X Communications,” IEEE Access, vol. 6, pp. 65 449–65 462, 2018.

[13] P. Xu and K. Cumanan, “Optimal Power Allocation Scheme for Non-Orthogonal Multiple Access With \( \alpha \)-Fairness,” IEEE J. Sel. Areas Commun., vol. 35, no. 10, pp. 2357–2369, 2017.

[14] Z. Wei et al., “Fairness Comparison of Uplink NOMA and OMA,” in Proc. IEEE 85th VTC Spring, Sydney, NSW, Australia, 2017, pp. 1–6.

[15] H. Xing et al., “Sum-Rate Maximization Guaranteeing User Fairness for NOMA in Fading Channels,” in Proc. IEEE WCNC, Barcelona, Spain, 2018, pp. 1–6.

[16] A. Chowdary et al., “Joint Resource Allocation and UAV Scheduling With Ground Radio Station Sleeping,” IEEE Access, vol. 9, pp. 124 505–124 518, 2021.

[17] Z. Ding et al., “Impact of User Pairing on 5G Nonorthogonal Multiple-Access Downlink Transmissions,” IEEE Trans. Veh. Technol., vol. 65, no. 8, pp. 6010–6023, 2016.

[18] M. Nemati et al., “RIS-Assisted Coverage Enhancement in Millimeter-Wave Cellular Networks,” IEEE Access, vol. 8, pp. 188 171–188 185, 2020.

[19] “Technical Specification Group Radio Access Network; Study on Channel Model for Frequencies From 0.5 to 100 GHz,” document TR 38.901, Version 14.3.0, 3GPP, 2017.