# Impact of User Pairing for Capacity Maximization in Uplink CR-NOMA

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***Abstract*—In this paper, user pairing in uplink cognitive radio non-orthogonal multiple access (CR-NOMA) networks is analyzed for maximizing the sum capacity. The existing user pairing techniques in conventional uplink CR-NOMA mainly focus on capacity maximization without considering the indvidual capacities of the users. This paper provides a comparison of the user pairing in CR-NOMA especially for uplink communication to highlight the tradeoffs between the individual user capacity gain and sum capacity gain. Importantly, the impact of cognitive and primary users distances from the BS is highlighted by pairing them and evaluating their performance gain. Finally, the simulation results of the user capacity of both primary and cognitive users are presented.**

## I. Introduction

Non-orthogonal multiple access (NOMA) is one of the promising radio access techniques considered for the future wireless communications due to high spectral efficiency and massive connectivity. One of the important part of NOMA is the user pairing or grouping to simultaneously serve multiple users using shared resource block but different transmit powers [1]. Additionally, the integration of NOMA in cognitive radio (CR) networks has a lot of benefits such as providing high spectral efficiency. However, the main challenges include the fair resource allocation and user pairing among the primary and cognitive users such that the quality of service (QoS) of both users can be guaranteed [2]. Motivated by the above challenges, user pairing in uplink CR-NOMA system is analyzed and the capacity performance of the users is evaluated.

## II. Capacity Analysis of Uplink CR-NOMA

In NOMA, multiple users are paired over the same resource block, which can be a time slot, a frequency channel, a scrambling code, or an orthogonal spatial degree of freedom. Consider a cognitive user ($CUE$), which is closer to the BS than the primary user ($PUE$). In UL NOMA, $CUE$ transmits its data with a higher power compared to the $PUE$ [3]. The adjustment of transmit power allocation is linked with target individual capacity of the users and their mutual interference management at the BS. At certain time $t$, both users simultaneously transmit their symbols $s_1$ and $s_2$ with power $\phi_1 P_t$ and $\phi_2 P_t$, respectively, where $\phi_1$ and $\phi_2$ are power allocation factors and $P_t$ is the total transmit power. The received signal at BS is given as

$$y = h_1\sqrt{\phi_1 P_t}s_1 + h_2\sqrt{\phi_2 P_t}s_2 + n, \quad (1)$$

where $s_1$ and $s_2$ are data symbols of $CUE$ and $PUE$ respectively, and $n$ is additive white Gaussian noise (AWGN) with mean 0 and variance $\lambda$. For data recovery at the BS, decoding starts from $CUE$, followed by $PUE$ through the SIC process. The BS first decodes the high power symbol $s_1$ by treating low power $s_2$ as noise. Then it performs SIC to recover $s_2$ by removing the previously decoded $s_1$ from $y$. The sum capacity in NOMA depends on different factors, such as transmit signal to noise ratio (SNR), the positions (correspondingly channel gains) of paired users, and their respective transmit PA factors.

Consider a pair of two users; $CUE$ paired with one of the $PUE$ from the list of primary users $PUE_1, PUE_2, ..., PUE_K$ at different distances from the BS, in UL NOMA system with channel gains $|h_1|^2$ and $|h_2|^2$, where $|h_1|^2 \geq |h_2|^2$. Channel $|h_i|$ is considered to be independent Rayleigh flat fading with channel coefficient $h_i \sim CN\ (0, \lambda_i = d_i^v)$ having mean 0 and variance $\lambda_i$ for the $BS - UE_i$ link, where $d_i$ is the $BS - UE_i$ distance, and v is the path loss exponent. The distances from BS to $CUE$ and $PUE$ are in the order $d_1 < d_2$, where $\phi_1 \geq \phi_2$.

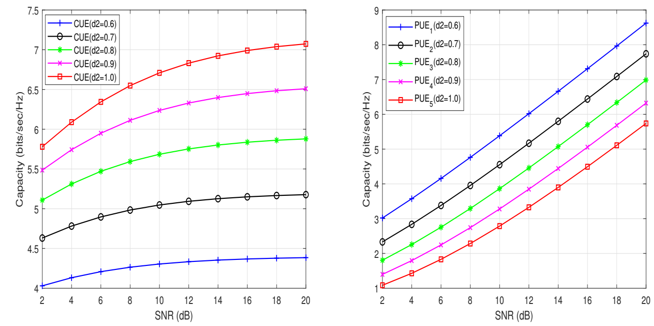


Fig. 1: Capacity of CUs and PUs at different transmit SNR.

The individual data rates of the paired users $CUE$ and $PUE$ can be written as

$$C_1 = \log_2\left(1 + \frac{\phi_1 P_t |h_1|^2}{N_o + \phi_2 P_t |h_2|^2}\right), \quad (2)$$

$$C_2 = \log_2\left(1 + \frac{\phi_2 P_t |h_2|^2}{N_o}\right). \quad (3)$$

Correspondingly, the sum capacity of the users can be calculated using eq. 2. and eq. 3, written as $C_{sum} = C_1 + C_2$.

In Fig. 1, it can be seen that the sum capacity depends on the appropriate pairing of the $CUE$ with a $PUE$ considering the individual capacity target i.e., 2bps. It is clear from the results that pairing $PUE_3$ with the $CUE$ will guarantee the QoS of both primary and cognitive users. Thereby user pairing has direct impact on the performance of uplink CR-NOMA network.

## III. Conclusion

This paper presents user pairing in uplink CR-NOMA where NOMA is used to achieve high spectral efficiency. Importantly, the capacity gain of the primary and cognitive users is analyzed considering different distances of the users from the BS. In uplink CR-NOMA the sum capacity depends on the user pairing because the individual user capacity of the primary and cognitive users contribute to it. Therefore, the pairing of the primary and cognitive users should be performed in such a way that the QoS of primary users must be guaranteed.

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## References

[1] Z. Ding, P. Fan, and H. V. Poor, "Impact of user pairing on 5G nonorthogonal multiple-access downlink transmissions," *IEEE Transactions on Vehicular Technology*, vol. 65, no. 8, pp. 6010–6023, 2016.

[2] F. Zhou, Y. Wu, Y. -C. Liang, Z. Li, Y. Wang and K. -K. Wong, "State of the Art, Taxonomy, and Open Issues on Cognitive Radio Networks with NOMA," *IEEE Wireless Communications*, vol. 25, no. 2, pp. 100-108, Apr. 2018.

[3] M. Gupta, S. Prakriya, "Performance of CSI-based Power Control and NOMA/OMA Switching for Uplink Underlay Networks with Imperfect SIC," *IEEE Transactions on Cognitive Communications and Networking*, Jun. 2022.