

Cooperative Power Domain Noma Transmission Using Relays

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Abstract

The non-orthogonal multiple access (NOMA) multiple access technique, due to its non-orthogonality and providing access to users together, which have the same frequency and time resource, made it a front runner to meet the need of high traffic requirements networks. In this paper, a downlink, NOMA, and cooperative NOMA (CNOMA) are compared with varying different parameters: source transmit power, user transmit power, and power allocation for achievable sum rates. Simulation results show that the CNOMA achieves a higher sum rate as compared to NOMA for all the parameters.

Keywords

Fairness, efficient relay selection range (ERSR), NOMA, multicast group, CNOMA, near user, far user, SNR, Sum rates

1. Introduction

Due to the high rise in data demand and intelligent devices, including modern wireless applications, the need for efficient communication technology is emergent, which can use current infrastructure [1]. Non-orthogonal multiple access (NOMA) has been regarded as the best suitable candidate for 5th-generation wireless communication. Cooperative communication is one of the most prominent techniques to enhance system performance, spatial diversity, and user coverage [2]. Cooperative relaying is considered the optimum solution for enhancing small-scale fading and improving system data throughput and spectral efficiency for users far from the base station. In Nabar et al.'s study [3] and that of Member [4], the demonstration of superiority in cooperative networks over non-cooperative techniques in achievable throughput has been investigated. In the research of Adam and Bettstetter [5], the energy required to receive data while users are cooperating has been studied. Hwang and Ko [6] proposed a mechanism to improve message complexity by developing a solution-based algorithm. In this paper, cooperative NOMA (CNOMA) flexible resource allocation mechanism was proposed; secondly, the

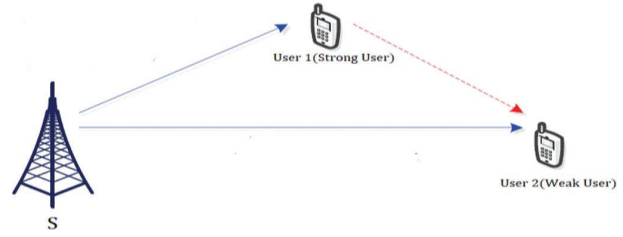
authors investigated the cooperative relay-sharing method to enhance user reliability and reception in multicast technology. The worst channel condition in the multicast group (MG) determines how modulation and coding schemes can be selected by base stations (BS). As a result, the worst channel condition constrains the multicast rate. The work regarding dual-stage cooperative multicast (CM) has been investigated to tackle this challenge and reach the highest possible multicast coverage comparisons in recent years. The multicast coverage ratio represents the number of users who can successfully receive compared to the number of MG users. Users with better channel conditions, also known as the successful users (SUs), can receive preferential treatment, which implies that BS can send data to those MG in the first stage, using the opportunistic multicast scheme (OMS). Those with bad channel conditions can be considered unsuccessful users (USU). In the second step, some SUs are chosen as user relays (URs), and these use device-to-device (D2D) technology to pass their reception signals to USUs. The advent of D2D allows MG users to collaborate more effectively. It prevents the cell-edge MG user from experiencing profound fading. Multicast systems' coverage ratio and throughput have been enhanced significantly.

However, under the NOMA-UR selection scheme for the effective and optimum purpose, each USU chooses the SUs that are within the relay selection range that is most efficient (ERSR) and can ensure effective reception, without considering the relationship between SU density and USU position.

2. Related Works

Recent cooperative networks with relay selection mechanisms have been studied as key enablers in the enhancement of user reception. To solve the issue of the low coverage efficiency problem, Zhang et al. [7] proposed a range division UR selection scheme. To minimize transmission time, Nam et al. [8] proposed two relay selection methods. Ikki and Ahmed [9] investigated the best relay method for achieving attenuation in resource consumption and full diversity order. The concept of opportunistic relay selection for the improvement of spectral efficiency was proposed in Nomikos et al.'s study [10]. As an effective means to improve the system efficiency full-duplex (FD)-NOMA, the same study has been explored together with buffer-aided (BA) relay grids, incorporated with NOMA and broadcasting technique. To ensure consistency with enhancing system efficiency and achievable rate, Huang and Lee [11] proposed NOMA-based diamond relay cooperative and non-cooperative. Balyan and Daniels [12] performed resource allocations with the help of relays. To address the problem of reception quality, Kim and Lee [13] formulated the cooperative relay system (CRS) technique. In Wang et al.'s study [14], the resource allocation was proposed to achieve both achievable rate and fairness. To minimize human errors and maximize performance in the same study, NOMA has been proposed and has been regarded as a possible solution to the problems of the next-generation wireless radio access network, a solution that can help in avoiding human error collisions and incident reduction. The outage probability of secondary users is calculated and simulated for cognitive radio network in Balyan's study [15]. Liu and Wang [16] proposed exact approaches with the aim of serving cell-edge users in which NOMA relay outperforms orthogonal multiple access (OMA) relay in both outage probability and outage capacity. Al-Ahmadi's study [17] uses two and three users scenarios to optimize the achievable max-min rates. Biyoghe and Balyan [18] propose a user group algorithm (UGA) that works based on maximization of fairness among users grouped for Multibeam Satellite Networks (NOMA-MBSNs), and the proposed UGA is superior to prevalent researches found in the literature.

The remainder of the paper is organized as follows. The cooperative broadcast channels are explained in Section 3, results and simulations are given in Section 4, and the paper is concluded in Section 5.



3. Cooperative Broadcast Channels

A relay broadcast channel (RBC) for single-antenna users is used. One user denoted as user 1 is the strong user; it has a stronger link or better channel conditions; the other user, denoted as user 2, is a weak user having poor channel conditions with the transmitter. The transmitter encodes an intended signal for these users depending upon their channel conditions – or in other words, different power allocation proportions are used for each user. More power is allocated to a weak user as compared to a strong user, which implies that the signal of the weak user has a high signal-to-noise ratio (SNR). Due to this, user 1 easily decodes user 2's signal even before decoding its own signal and can subtract it from total signal to retrieve its own signal, i.e., successive interference cancellation (SIC) is employed. The user's cooperation is used for improving the achievable rate of the weak user [19, 20].

The received signal of user 1 is

$$y_1 = h_1 x + w_1 \quad (1)$$

and received signal by user 2 is

$$y_2 = h_2 x + h_{12} x_1 + w_2 \quad (2)$$

where h_1 , h_2 , and h_{12} denote channel coefficients from transmitter to users 1 and 2 and between users 1 and 2 (i.e., cooperative link), respectively [12]; the signal x possesses the information of two users and x_1 is the message sent by user 1 to 2; and w_1 and w_2 denote, respectively, additive white Gaussian noise (AWGN) at the receivers of users 1 and 2, shown in Figure 1.

The achievable rates for user 1 is

$$r_1 = \log_2 \left(1 + \frac{P |h_1|^2}{\sigma^2} \right) \quad (3)$$

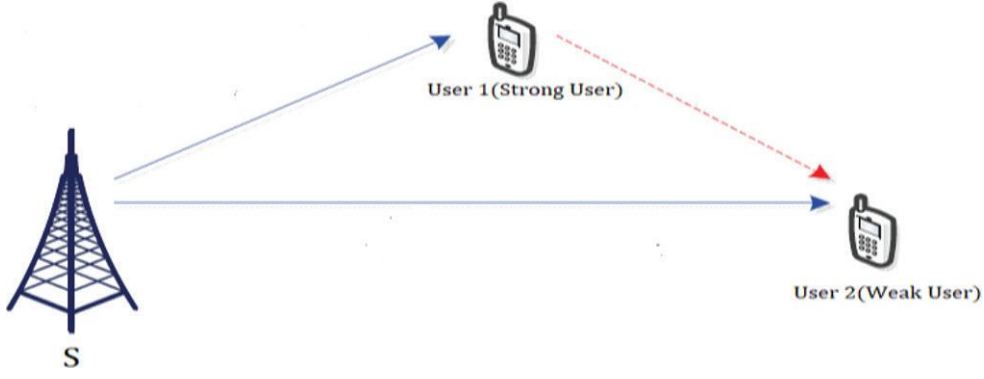


Figure 1: Two user cooperative NOMA. NOMA, non-orthogonal multiple access.

The achievable rate for user 2 will be

$$r_2 = \min(r_{1-2}, r_{2-2}) = \min \left\{ \log_2 \left(1 + \frac{(1-i)P |h_1|^2}{iP |h_1|^2 + \sigma^2} \right), \log_2 \left(1 + \frac{(1-i)P |h_2|^2 + P_1 |h_{12}|^2}{iP |h_2|^2 + \sigma^2} \right) \right\} \quad (4)$$

where i is the power allocation fraction of total transmit power P from the source that is allocated to user 1's signal and P_1 is power used for cooperation, given to user 1, being a strong user. All the users are assumed to be equipped with a single antenna; the source is assumed to know the channel coefficients of all the users and the user used as a relay knows the channel coefficient of cooperative links. The user working as a relay is selected based on its coverage area [21] and its capability to decode its own signal and the signal of the weak user. A scenario of three users, CNOMA, is taken in which all users are assumed to have single antennas, the source knows the channel coefficients of all the users, and the relays (strong users) are aware of the channel coefficient of link between them and the weak user. In this scenario, two strong users act as a relay for a third user and they have the capability to decode their signal with the signal of the weak user. The received signal at the three users' end will be as indicated in the study of Balyan and Daniels [12].

The received signal of user 1 is

$$y_1 = h_1 x + w_1 \quad (5)$$

The received signal of user 2 is

$$y_2 = h_2 x + h_{12} x_1 + w_2 \quad (6)$$

The received signal of user 3 is

$$y_3 = h_3 x + h_{13} x_1 + h_{23} x_2 + w_3 \quad (7)$$

where h_3 is the channel coefficient of the link between source and user 3, h_{13} denotes channel coefficient of the link between users 1 and 3, h_{23} denotes channel coefficient of the link between users 2 and 3, and w_3 denotes AWGN noise at user 3's receiver, shown in Figure 2.

The signal x possesses the information of three users, x_1 is the message sent by user 1 to 3, and x_2 is the message sent by user 2 to 3. Also,

$$|h_1|^2 > |h_2|^2 > |h_3|^2 \quad (8)$$

The achievable rates for user 1 are

$$r_1 = \log_2 \left(1 + \frac{iP |h_1|^2}{\sigma^2} \right) \quad (9)$$

For user 2, it will be

$$r_2 = \min \left\{ \log_2 \left(1 + \frac{jP |h_1|^2}{iP |h_1|^2 + \sigma^2} \right), \log_2 \left(1 + \frac{jP |h_2|^2 + \beta P_1 |h_{12}|^2}{iP |h_2|^2 + \sigma^2} \right) \right\} \quad (10)$$

and

$$r_3 = \min \{ r_{1-3}, r_{2-3}, r_{3-3} \} \quad (11)$$

$$r_{2-3} = \log_2 \left(1 + \frac{kP |h_2|^2 + (1-\beta)P_1 |h_{12}|^2}{iP |h_2|^2 + jP |h_2|^2 + \beta P_1 |h_{12}|^2 + \sigma^2} \right) \quad (12)$$

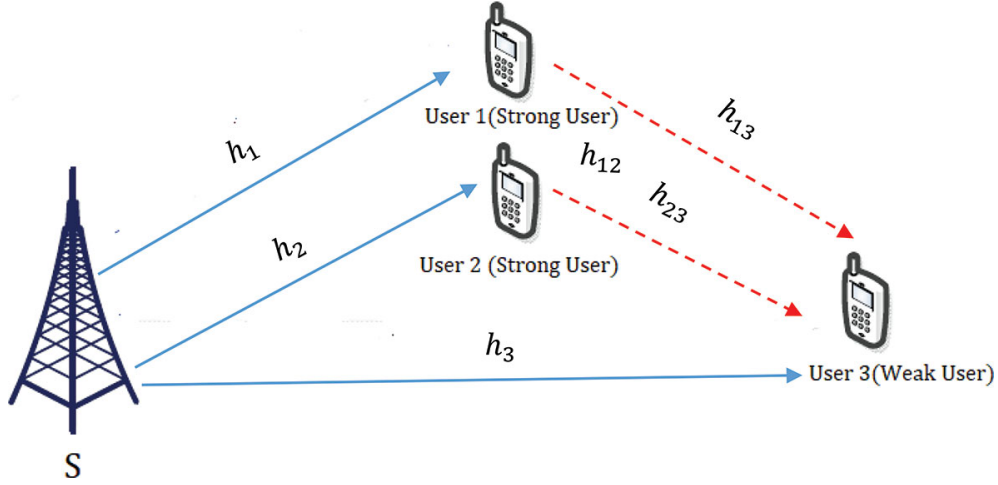


Figure 2: Three user CNOMA. CNOMA, cooperative NOMA; NOMA, non-orthogonal multiple access.

$$r_{3-3} = \log_2 \left(1 + \frac{kP|h_3|^2 + (1-\beta)P_1|h_{13}|^2 + P_2|h_{23}|^2}{iP|h_3|^2 + jP|h_3|^2 + \beta P_1|h_{13}|^2 + \sigma^2} \right) \quad (13)$$

$$r_{1-3} = \log_2 \left(1 + \frac{kP|h_1|^2}{iP|h_1|^2 + jP|h_1|^2 + \sigma^2} \right) \quad (14)$$

where i, j, k denotes power allocation fraction of total transmit power P from the source that is allocated to the signals of users 1, 2, and 3, respectively; P_1, P_2 is power used for cooperation given to user 1, user 2 being a strong user; σ^2 is the AWGN variance; and β is the power allocation coefficient [12, 15].

In a similar way, this can be extended to r relays and n users, and can apply in relation to any r^{th} relay working as a relay for n users.

All the signals of n users are superimposed by BS and transmitted to the relay, which is decoded and after extracting its own signal is forwarded to the users by the relay.

The superimposed signal of n users with r^{th} relay signal will be

$$y_r = \sqrt{P_1 P_r} x_1 + \sqrt{P_2 P_r} x_2 + \dots + \sqrt{P_n P_r} x_n + \sqrt{P_{n+1} P_r} x_{n+1} \quad (15)$$

which can be reduced in generalized form as

$$y_r = \sqrt{P_r} \left(\sum_{u=1}^n \sqrt{P_u} x_u + \sqrt{P_{n+1}} x_{n+1} \right) \quad (16)$$

where x_u denotes signal and P_u the power coefficient of the u^{th} user, and P_r is the power coefficient of the r^{th} relay.

The signal received by the r^{th} relay will be

$$z_r = h_r y_r + w_r \quad (17)$$

where h_r and w_r denote the channel coefficient between relay and BS and noise at relay, respectively. After reception of this superimposed signal, the relay will extract its own signal and transmit the remaining signal to users as

$$z'_r = \sqrt{P_{tr}} \sum_{u=1}^n \sqrt{P_{ru}} x_{ru} \quad (18)$$

where P_{tr} denotes the total transmitted power of the r^{th} relay. The SIC will be employed by any p^{th} user to detect its own signal [21] and the achievable rates will be calculated using Eqs. (9)–(11).

4. Results and Simulations

The present study discusses the obtaining of results for non-fading channels, for example, high frequency line of sight (LoS) mm wave, visible light communication (VLC) channels for indoor LoS, and THz radio frequency (RF) channels. A single cell environment is considered with BS placed at the center. The total number users considered are five; two users are acting as relays while the remaining are far users or weak users. The radius of the cell is 250 m and the users are considered to be static for a time slot.

In Figure 3, the sum rate of the NOMA and CNOMA schemes is compared using various source transmit powers for three users' scenario. The CNOMA is a clear winner in increasing the sum rates

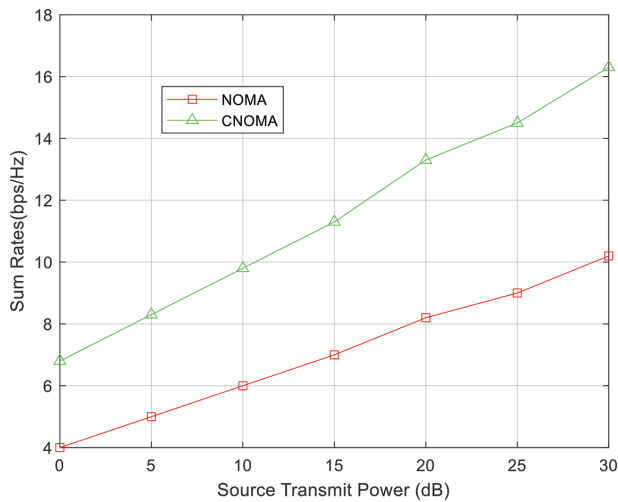


Figure 3: Sum rates of NOMA and CNOMA compared with variable source transmit power. CNOMA, cooperative NOMA; NOMA, non-orthogonal multiple access.

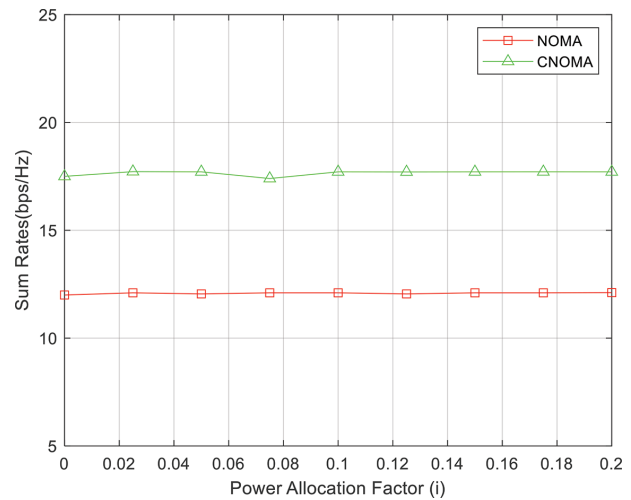


Figure 5: Sum rates of NOMA and CNOMA compared with variable power allocation factor. CNOMA, cooperative NOMA; NOMA, non-orthogonal multiple access.

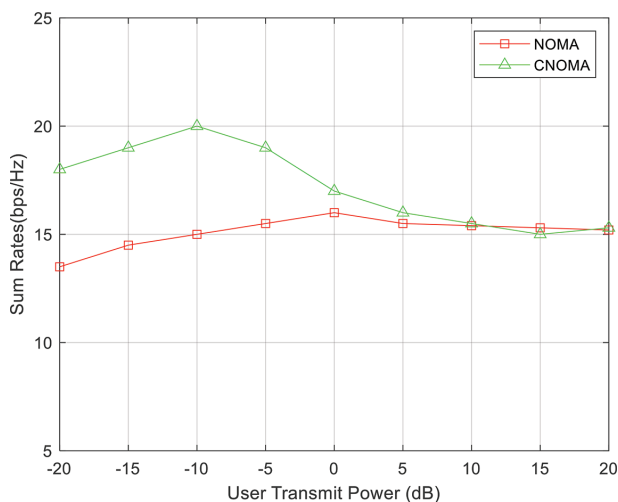


Figure 4: Sum rates of NOMA and CNOMA compared with variable user transmit power. CNOMA, cooperative NOMA; NOMA, non-orthogonal multiple access.

as compared to the traditional NOMA. As the SNR increases, the difference between NOMA and CNOMA increases too.

In Figure 4, the user's transmit power impact on the sum rates is compared for NOMA and CNOMA, considering that two near users (1 and 2) have equal transmit powers in the presence of one far user

(user 3). From Figure 4, it is clear that the sum rate of CNOMA decreases with user transmit power > -10 , which is due the fact that user 3's sum rate depends on the links with users 1 and 2 and also due to inter-user interference (IUI), which increases as a result of an increase in the user's power. When transmit power is > 0 , the sum rate stabilizes as the power of a near user or the direct link user becomes easily decodable.

In Figure 5, different power allocation factors are used to compare the performance of NOMA and CNOMA, and the results show that the achievable sum rates for both of these remain the same for a variable range of the power allocation factor.

5. Conclusion

The presented research compares the NOMA and CNOMA; the CNOMA makes use of strong users, which acts as a relay. The users on the edge of the cell or at a poor coverage location would only be able to receive signals of a poor quality; given the prevalence of such circumstances, the relay, or the strong users acting as a relay, can receive and transmit these signals at a better quality, with the result that these can be decoded more easily. The results of the present study prove that the CNOMA outperforms the NOMA for all the variable parameters characterized by the requirement for a complex receiver. Future

research can extend to studying the complexity of the receiver and the delay arising from the complexity involved in decoding the received signals.

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