Uplink NOMA-OFDM-IM with Constellation Rotation

Mohammed Shahriar Kamal, Soo Young Shin*
Department of IT Convergence Engineering
Kumoh National Institute of Technology

msrkamal@kumoh.ac.kr, *wdragon@kumoh.ac.kr

Abstract

In this paper, we propose to combine the non-orthogonal multiple access (NOMA) and orthogonal frequency division multiplexing-index modulation (OFDM-IM) by exploiting the constellation rotation to enhance the capacity with low computational complexity SIC operations. We considered an uplink scenario with four users, where users transmit information by applying IM to activate certain subcarriers and by QPSK-modulated symbols over the active subcarriers. Additionally, a fixed constellation rotation is applied. SIC will be used by the base station (BS) to detect the signals according to the decreasing order of power. The simulation result shows that the proposed system outperforms conventional schemes, in terms of the sum rate.

I. Introduction

Generally, in uplink NOMA, every user's signal is decoded by utilizing the successive interference cancellation (SIC) operation, which leads to higher errors and thereby limits the number of users [1].

Recently, for beyond 5G, the integration of NOMA, orthogonal frequency division multiplexing (OFDM), and index modulation (IM) has been receiving a lot of attention to achieve higher spectral efficiency and improved error performance [2], [3]. However, the number of detection and cancellation operations is proportional to the number of superimposed users on the channel. On the other hand, to further improve the error performance and reduce the complexity of downlink IM -NOMA constellation rotation is utilized in [4].

In this paper, we propose to integrate NOMA-OFDM-IM with constellation rotation for an uplink scenario with four users, which will have better spectral efficiency. Information will be transmitted by applying IM to activate certain subcarriers and by QPSK-modulated symbols over the active subcarriers. Additionally, the QPSK will go through a fixed constellation rotation. The transmitted signals of the four users will be received at the BS with different power levels. SIC will be used to decode the signals according to the decreasing levels of power. The rotation of constellations along with different power levels eases up the signal detection process.

II. Method

Let us consider an uplink (UL) NOMA system based on OFDM operating under frequency-selective Rayleigh fading channels. Users (u) independently generate OFDM-IM signals to transmit to the base station (BS) using the same frequency and time slots. The BS receives signals from multiple users as a composite signal. In this paper, a scenario with four users ($u = 4$) is considered, as shown in Fig. 1. The $UE_1 \rightarrow$ BS, $UE_2 \rightarrow$ BS, $UE_3 \rightarrow$ BS, $UE_4 \rightarrow$ BS channel gains are represented as $|h_1|^2$, $|h_2|^2$, $|h_3|^2$, $|h_4|^2$ respectively, such that $|h_1|^2 > |h_2|^2 > |h_3|^2 > |h_4|^2$. The users transmit their data with powers P_1, P_2, P_3, and P_4 respectively, and the powers of the received signal at the BS are in the order of $P_1' > P_2' > P_3' > P_4'$.

Each of the users transmits a total of B_u bits, where $u \in \{UE_1, UE_2, UE_3, UE_4\}$. The B_u bits are divided into g groups, each containing $b_u = B_u/g$ bits. The ε^{th} subblock $z_u(\varepsilon)$ of any user is considered as the process of creating each subblock is the same. The b_u bits are charted into subblocks of size $d_u = {}^{N}/_{g}$, where N is the total number of subcarriers. Then, to create OFDM-IM subblock, the bits are divided into two parts: $b_{u,1}$ and $b_{u,2}$. The former is to determine k_u active subcarriers in a subblock employing a look-up table [5] and producing the active subcarrier indices as $I_u(\varepsilon) = \{i_{u,1}(\varepsilon), \ldots\ldots, i_{u,k_u}(\varepsilon)\}$ where $i_{u,\lambda}(\varepsilon) \in \lambda = 1, \ldots\ldots, k_u$. And the latter ($\log_2 M$) is to determine the vector of modulated symbols $\mathbf{c}_u(\varepsilon) = [c_{u,1}(\varepsilon), \ldots\ldots, c_{u,k_u}(\varepsilon)]$. The CSI between the particular users and the BS is obtained by the users through overhearing the broadcast downlink common reference signals [6], and it is assumed that channel estimation is perfect. All the users exploit QPSK modulation, and to enhance the minimum distance between the constellation points (Euclidean distance) of the composite multiuser signal at the BS, UE_2 and UE_4 rotate the constellation by 45° while UE_1 and UE_3 rotate the constellation by 0°. The users create their OFDM-IM signal block based on the $I_u(\varepsilon)$ and $\mathbf{c}_u(\varepsilon)$. Eventually, the messages are transmitted through frequency-selective Rayleigh fading channels.

At the receiving side, the BS decodes the signals of multiple users based on the decreasing order of their received powers ($P_1' > P_2' > P_3' > P_4'$). The received signal at the BS can be written as

$$\mathbf{y} = \sum_{u=1}^{U} \sqrt{P_u}\, \mathrm{diag}(\mathbf{h}_u) x_u e^{j\theta_u} + \mathbf{w}_u, \qquad (1)$$

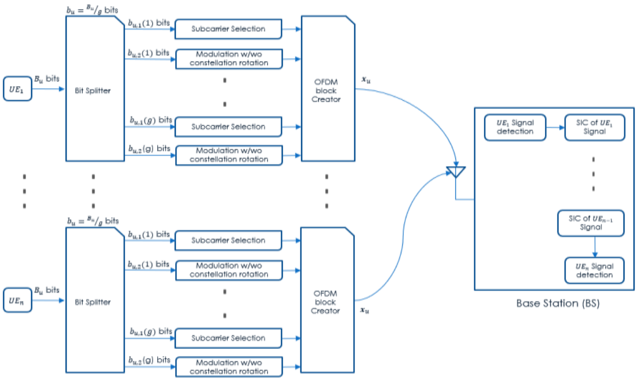

Figure 1 System Model

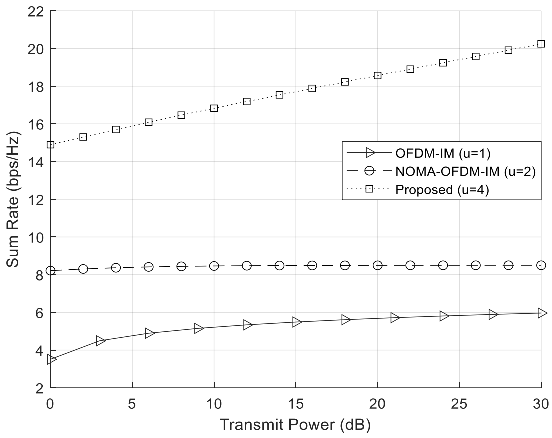

Figure 2 Sum capacity of proposed system compared to NOMA-OFDM-IM and OFDM-IM

where $\mathrm{diag}(\mathbf{h}_u) = \mathrm{diag}([h_u(1) \dots, h_u(N)]^T)$ and $\mathbf{w}_u = [w_u(1) \dots, w_u(N)]^T$ are the channel matrix and noise vector for the four users in the frequency domain, respectively. The BS can directly detect the UE_1 signal first by treating the other users signals as noise.

$$\hat{\mathbf{x}}_{UE_1}(\varepsilon) = \underset{\mathbf{x}_1 \in \chi}{\arg\min} ||\mathbf{y}(\varepsilon) - \sqrt{P'_1}\mathrm{diag}(\hat{\mathbf{h}}_1(\varepsilon))\mathbf{x}_1 e^{j\theta_{UE_1}}||^2, \quad (2)$$

where $\mathbf{y}(\varepsilon)$ and $\mathrm{diag}(\hat{\mathbf{h}}_1(\varepsilon))$ are the received signal vector and the channel matrix for the ε^{th} subblock, respectively. Once $\hat{\mathbf{x}}_{UE_1}$ is decoded, the BS detracts its effect from $\mathbf{y}$ as a step of SIC. We denote the signal after SIC as $\mathbf{y}_{UE_1,\mathrm{SIC}}$. Then the BS tries to retrieve UE_2's transmitted vector by executing a similar operation, as done earlier for UE_1, on $\mathbf{y}_{UE_1,\mathrm{SIC}}$ while treating signals from UE_3 and UE_4 as noise. Similarly, the BS detects UE_3 and UE_4 signals by performing SIC.

III. Result

Figure 2 shows the comparison of the proposed scheme, NOMA-OFDM-IM, and OFDM-IM in terms of the sum capacity. We considered activation of $k = 2$ subcarriers out of $n = 4$ in a subblock. As shown in Fig. 2, the proposed scheme outperforms the conventional NOMA-OFDM-IM and OFDM-IM.

IV. Conclusion

We proposed an uplink NOMA-OFDM-IM scheme for four users to enhance the capacity by utilizing constellation rotation. Moreover, the signal of each user can be conveyed with additional index bits by applying OFDM-IM. In terms of achievable data rates, the simulation result depicts that the proposed scheme outperforms conventional OFDM-IM and NOMA-OFDM-IM.

ACKNOWLEDGMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government. (MSIT) (No.2022R1A2B5B01001994) and in part by Institute of Information & communications Technology Planning & Evaluation (IITP) grant funded by the Korea government (MSIT) (No. 2021-0-02120, Research on Integration of Federated and Transfer learning between 6G base stations exploiting Quantum Neural Networks).

REFERENCES

[1] Dai, Linglong, et al. "Non-orthogonal multiple access for 5G: solutions, challenges, opportunities, and future research trends." IEEE Communications Magazine 53.9 (2015): 74-81

[2] Arslan, Emre, Ali Tugberk Dogukan, and Ertugrul Basar. "Index modulation-based flexible non-orthogonal multiple access." IEEE Wireless Communications Letters 9.11 (2020): 1942-1946.

[3] Shahab, Muhammad Basit, et al. "Index modulation aided uplink NOMA for massive machine type communications." IEEE Wireless Communications Letters 9.12 (2020): 2159-2162.

[4] Almohamad, Abdullateef, et al. "Low complexity constellation rotation-based SIC detection for IM-NOMA schemes." 2020 IEEE 92nd Vehicular Technology Conference (VTC2020-Fall). IEEE, 2020.

[5] Başar, Ertuğrul, et al. "Orthogonal frequency division multiplexing with index modulation." IEEE Transactions on signal processing 61.22 (2013): 5536-5549.

[6] Jiang, Xiwen, and Florian Kaltenberger. "Channel reciprocity calibration in TDD hybrid beamforming massive MIMO systems." IEEE Journal of Selected Topics in Signal Processing 12.3 (2018): 422-431.