Capacity analysis Of IRS Assisted RSMA-OAM for next generation of wireless communication

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ABSTRACT

In this paper, we propose a novel approach for enhancing the performance of next generation of wireless communication systems by utilizing intelligent reflective surface (RS) and orbital angular momentum (OAM). Precisely, the use of IRS to assist in the transmission of OAM-based multiplexed signals. By combining the IRS with OAM-based rate-splitting multiple access (RSMA), we show that our proposed approach can significantly improve the system capacity for next generation of wireless communication systems.

Keywords: Orbital angular momentum, Rate splitting multiple access, Intelligent reflecting surfaces

Ⅰ. INTRODUCTION

6G wireless communication systems are expected to provide high data rates, low latency, and high energy efficiency to meet the demands of emerging applications such as virtual reality, internet of things, and machine learning [1]. To achieve these goals, new technologies such as intelligent reflecting surfaces (IRS) [2], orbital angular momentum (OAM) [3] and rate splitting multiple access (RSMA) [4] are under consideration for the design of 6G wireless communication systems. IRS are programmable meta-surfaces with the ability to manipulate the phase and amplitude of the reflected signal and it can enhance the performance of wireless communication systems by reducing the path loss and increasing the signal-to-noise ratio. OAM which is a property of electromagnetic waves provides an additional degree of freedom for data transmission which is the angular momentum of a photon along its propagation axis. To enhance the channel capacity of IRS assisted cellular communication for multiple users, IRS is integrated with RSMA-OAM for next generation of cellular communication. Hence, a novel scheme called IRS assisted RSMA-OAM system is proposed in this paper. Furthermore, cell capacity of near user and far user are also analyzed and compared with IRS assisted NOMA-OAM to prove the superiority of the proposed system

Ⅱ. SYSTEM MODEL

The IRS assisted RSMA-OAM system model is shown in Fig. 1. This system model consists of a transmit UCA with M antenna elements, an IRS array with $K \times K$ elements, and two users namely cell center user (CCU) and cell edge user (CEU) both of which are equipped with a single UCA having N antenna elements. The IRS array is between the transmitter UCA and users and the CCU is near to the IRS while CEU is far from the IRS. Distance and channel between transmitter and IRS are d, h, between IRS and CCU d_1, g_{ccu} and IRS and CEU d_2, g_{CEU}. IRS is in line of sight of both transmitter UCA and users and the direct path between the transmitter UCA and users is obstructed by the obstacle. Hence, the communication takes place with the help of IRS. Using this configuration, transmitter UCA transmit multiple OAM modes (0 to $M-1$ OAM modes) towards the IRS and IRS reflect the signal towards the users. φ_n and Ψ_n is the angular displacement between the elements of transmit UCA and UCAs at the users, respectively. The channel capacities of CCU and CEU for the proposed system are discussed in section 3.

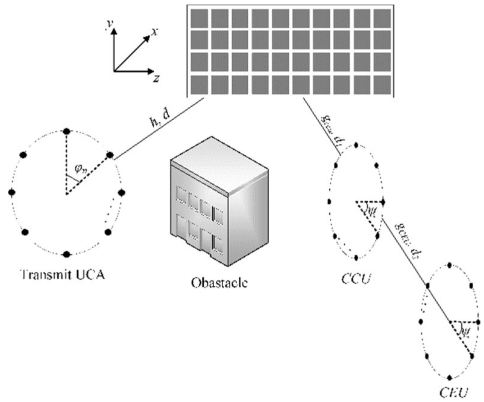

Fig. 1: Proposed IRS-RSMA-OAM for downlink communication

Ⅲ. CHANNEL CAPACITY ANALYSIS

The channel capacities that can be achieved by CCU and CEU for the proposed system can be represented [5].

$$R_{CCU}=\sum_{q_{ccu}=1}^{Q_{ccu}}\left\{\log_2\left(1+\rho\frac{\gamma_{ccu}^{c}}{N}\tau_{q_{ccu}}^{2}\right)+\log_2\left(1+\rho\frac{\gamma_{ccu}^{p}}{N}\tau_{ccu}^{2}\right)\right\}. \quad (1)$$

$$R_{CEU}=\sum_{q_{CEU}=1}^{Q_{CEU}}\left\{\log_2\left(1+\rho\frac{\gamma_{CEU}^{c}}{N}\tau_{CEU}^{2}\right)+\log_2\left(1+\rho\frac{\gamma_{CEU}^{p}}{N}\tau_{CEU}^{2}\right)\right\}. \quad (2)$$

where

$$\gamma_i^{c}=\frac{p_c h\emptyset g_i}{p_1^{p}h\emptyset g_i+p_2^{p}h\emptyset g_i+1}$$

and

$$\gamma_{CCU}^{p}=\frac{p_{CCU}^{p}h\emptyset g_{CCU}}{p_{2CEU}^{p}h\emptyset g_{CCU}+1},\gamma_{CEU}^{p}=\frac{p_{CEU}^{p}h\emptyset g_{CEU}}{p_{CCU}^{p}h\emptyset g_{CEU}+1}$$

Where $i\epsilon\,(CCU, CEU)$, ρ is the transmit SNR for each OAM modes. p_c, p_{CCU}^{p} and p_{CCU}^{p} are the power allocation for common part, private part of CCU and CEU, respectively. In addition, $\tau_{q_{ccu}}^{2}$ and $\tau_{q_{CEU}}^{2}$ are the singular value of the CCU and CEU channel matrix. Q is the rank of the channel matrix and $\emptyset$ is the reflection induced by IRS.

IV. RESULT ANALYSIS

In this section the capacity results of the proposed system are analyzed and compared with IRS-NOMA-OAM. Simulation parameters are $\lambda = 0.01$m, d=100m, d_1=100m, d_2 = 150m, M=5, N=5, K=16, ϕ=180°. Fig. 2 shows that the proposed scheme performs better in terms of higher capacity as compared to IRS-NOMA-OAM.

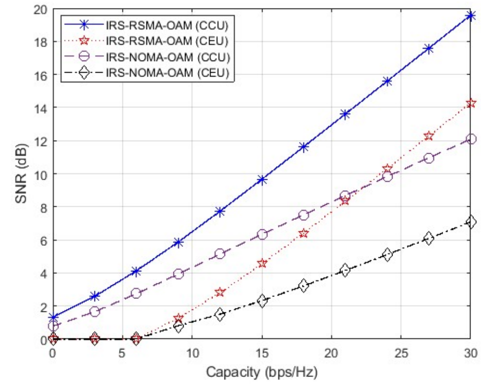

Fig. 2: CCU and CEU channel capacity vs. transmit SNR

Because multiple channels utilized by different OAM modes can carry multiple symbols towards the CCU and CEU simultaneously.

V. CONCLUSION

The proposed IRS-RSMA-OAM scheme for cellular communication enhanced the channel capacities of different users which are proved by simulation and can be good possible solution for next generation of wireless communication.

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REFERENCES

[1] Liu, Guangyi, Na Li, Juan Deng, Yingying Wang, Junshuai Sun, and Yuhong Huang. "The SOLIDS 6G mobile network architecture: Driving forces features and functional topology." *Engineering* 8 (2022): 42-59.

[2] Jiang, Wei, and Fa-Long Luo. "Intelligent Reflecting Surface-Aided Communications for 6G." (2023): 295-362.

[3] ISMAIL, ARIF MAWARDI, and MOHAMED NASRUN OSMAN. "A Review of Orbital Angular Momentum Vortex Waves for the Next Generation Wireless Communications."

[4] Dizdar, Onur, Yijie Mao, Wei Han, and Bruno Clerckx. "Rate-splitting multiple access: A new frontier for the PHY layer of 6G." In 2020 IEEE 92nd Vehicular Technology Conference (VTC2020-Fall), pp. 1-7. IEEE, 2020.

[5] Chen, Ruirui, Fengzhi Cheng, Jinyang Lin, Liping Liang, and Yanjing Sun. "Performance Analysis of Rate Splitting Multiple Access Based Vortex Wave Communications." IEEE Wireless Communications Letters (2022).