A Survey on Rate-Splitting Multiple Access for Downlink Networks

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Abstract

Rate-Splitting Multiple Access (RSMA) has emerged as a promising technique to enhance the performance of downlink networks, especially for beyond 5G systems where a high number of users are served concurrently over the same bandwidth. This survey provides a concise overview of recent advancements in RSMA-assisted downlink networks focusing on rate optimization metrics such as weighted sum-rate maximization and max-min fairness. We discuss the technical aspects of key research works, their applicability in various scenarios, and highlight challenges and open issues for future research.

Ⅰ. Introduction

The exponential growth of wireless data traffic and the proliferation of connected devices necessitate advanced multiple access techniques for future wireless networks. Rate-Splitting Multiple Access (RSMA) has gained significant attention as a flexible and robust approach to manage multi-user interference in downlink transmission [1,2]. By splitting user messages into common and private parts, RSMA enables efficient interference management through superposition coding and successive interference cancellation (SIC).

Unlike traditional multiple access schemes such as Non-Orthogonal Multiple Access (NOMA) and Space-Division Multiple Access (SDMA), RSMA offers a continuum between fully decoding interference and treating interference as noise. This adaptability allows RSMA to achieve better spectral efficiency, enhanced fairness, and robustness to imperfect channel state information at the transmitter (CSIT).

This survey reviews recent research on RSMA-assisted downlink networks, focusing on optimization techniques for rate performance. We categorize the literature based on key optimization metrics and discuss the applicability of RSMA in various network scenarios.

Ⅱ. State-of-the-Art Research on RSMA-Assisted Downlink Networks

A. Weighted Sum-Rate Maximization

Weighted sum-rate (WSR) maximization is a fundamental metric for evaluating the performance of multi-user communication systems. RSMA has been shown to outperform conventional NOMA and SDMA in maximizing WSR under both perfect and imperfect CSIT conditions.

Mao *et. al.* [1] demonstrated that RSMA can efficiently handle heterogeneous user requirements and massive connectivity by appropriately allocating power between common and private streams. The authors applied RSMA in both underloaded and overloaded regimes, showing significant gains over traditional schemes.

In coordinated multi-point (CoMP) scenarios, RSMA has been integrated to enhance network throughput. Mao *et. al.* [3] investigated the application of generalized RSMA in CoMP joint

transmission, solving the WSR maximization problem using the Weighted Minimum Mean Square Error (WMMSE) algorithm.

The use of RSMA in Simultaneous Wireless Information and Power Transfer (SWIPT) systems was explored by Mao et al. [4]. By utilizing the common stream for both data transmission and energy harvesting, the proposed RSMA scheme improved the WSR of information receivers while satisfying the energy requirements of energy receivers.

B. Max-Min Fairness Optimization

Maximizing the minimum rate among users (max-min fairness) is critical for ensuring equitable service in multi-user networks. RSMA has been applied to achieve max-min fairness in multicast and multi-group scenarios.

Joudeh and Clerckx [5] considered a multigroup multicast system where users are grouped based on content interests. They proposed an RSMA-based beamforming strategy that significantly improved the minimum achievable rates compared to conventional schemes.

In cooperative networks, Mao [6] studied the optimization of precoders, message splitting, and time-slot allocation in a RSMA framework to maximize the minimum rate. By allowing users to assist in relaying, the cooperative RSMA scheme enhanced fairness among users.

III. Conclusion

RSMA has shown great potential in enhancing the performance of downlink networks by effectively managing multi-user interference. This survey reviewed key research contributions focusing on rate optimization metrics such as weighted sum-rate maximization and max-min fairness. While significant progress has been made, challenges remain in generalizing RSMA schemes, integrating advanced precoding techniques, and applying RSMA to diverse network scenarios. Addressing these challenges will pave the way for RSMA to play a crucial role in future wireless communication systems.

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