A Review on Cache-Enabled Rate-Splitting Multiple Access Schemes

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Abstract

The combination of wireless edge caching and rate splitting multiple access (RSMA) can significantly lessen the perceived latency of end users. This short survey explores various approaches and implementations of cache-enabled RSMA schemes, highlighting the technical details, and analyzing performance evaluation. We also draw insights from recent studies to highlight the current advancements in this new research trend.

Ⅰ. Introduction

The combination of caching methods with Rate-Splitting Multiple Access (RSMA) has become a viable method to improve network efficiency and user experience in the constantly changing field of wireless communication. Caching, the process of storing frequently requested data near the user, decreases latency and relieves the strain on central networks by decreasing the need for repeated data retrievals from far servers. RSMA is a complex multiple access technology that partitions data streams into numerous layers, improving transmission to suit users with different channel circumstances. The combination of caching and RSMA offers a synergistic solution that capitalizes on the respective advantages of both technologies. By integrating caching's capacity to provide rapid access to popular content with RSMA's proficiency in effectively managing spectrum resources and mitigating interference, networks may attain elevated data rates, better dependability, and improved overall performance. This integration is especially beneficial in situations with a large volume of users and a wide range of needs, making it an essential element in the development of future wireless networks.

Ⅱ. Literature Review

The work in [1] introduces an advanced RSMA scheme that minimizes redundancy by assuming a unified private part for users requesting the same content, thereby reducing inter-user interference. It solves the original problem by decomposing it into two subproblems, one focuses on long-term caching decision optimized via dynamic programming and another one concentrates on short-term RSMA resource allocation optimized using an alternating optimization method with one-dimensional search. The results demonstrated through simulations indicate that cache-enabled RSMA outperforms traditional RSMA, NOMA, and random cache strategies in terms of reducing system latency.

The paper [2] addresses the optimization of latency reduction in networks involving multiple limited cache capacity base stations (BSs) serving multiple users utilizing RSMA and cooperative caching. Any BS first checking for the requested file in its local cache, then querying neighboring BSs before finally contacting the back-end server if needed. The system model also considers the popularity of content and its distribution among the users. The authors decompose the main optimization problem into two subproblems: caching policy optimization (solved using dynamic programming) and RSMA resource allocation (handled via alternating optimization with one-dimensional search).

The work of [3] focuses on enhancing the performance of wireless caching networks using RSMA and dynamic recommendation systems to minimize latency. The authors explore how dynamic content recommendation can impact user requests and how RSMA can optimize resource allocation to reduce system latency. The paper addresses a complex optimization problem involving joint content caching, recommendation, and RSMA resource allocation. It also offers a detailed theoretical and practical framework for future enhancements in wireless networks technologies.

The work of [4] explores the application of RSMA for enhancing multigroup multicast beamforming within a cache-enabled Cloud Radio Access Network (C-RAN). The study aims to maximize the minimum weighted rate among all users while ensuring that base station transmit power and backhaul capacity constraints are adhered to. It proposes a system where users requesting the same content are grouped together and served by a cluster of base stations (BSs). The optimization involves dynamic BS clustering, message splitting, and designing beamforming vectors. The simulation results provided in the study demonstrate that the

proposed RSMA approach significantly outperforms traditional methods like Non-Orthogonal Multiple Access (NOMA) in terms of reducing system latency and improving the fairness of rate distribution among users. The use of multicast beamforming and RSMA in a cache-enabled C-RAN context effectively reduces the required backhaul capacity, which is a major advantage in network scenarios where backhaul is a limiting factor.

Ⅲ. Discussion

Through insights taking from the current state-of-the-art works we just discussed, the potential of collaboration among caching strategies and RSMA are quite clear, especially in improving the latency for end users. This integration leverages the strengths of both technologies, providing several key benefits:

- **Enhanced Spectral Efficiency:** RSMA optimizes the use of the available spectrum by allowing simultaneous transmission of multiple data streams to users with different channel conditions. When integrated with caching, this ensures that cached content can be delivered more efficiently, even in congested network environments. The combination leads to better utilization of spectral resources, reducing the overall transmission time and increasing throughput.
- **Improved Quality of Services (QoS):** Caching reduces latency by storing popular content closer to the end users, while RSMA ensures that data is transmitted in a way that accounts for varying user channel conditions. Together, they enhance the Quality of Service (QoS) by providing faster and more reliable access to content. Users experience fewer delays and interruptions, particularly during peak usage times, leading to a more seamless and satisfactory user experience.
- **Scalability and Flexibility:** The integration of RSMA into caching schemes provides a scalable and flexible solution that can adapt to various network conditions and user demands. RSMA's ability to handle different user requirements and caching's capability to pre-store popular content make this combination ideal for networks with a large and diverse user base. This scalability is crucial for the deployment of next-generation networks, such as 5G and beyond.
- **Energy Efficiency:** Efficient spectrum usage and reduced backhaul traffic contribute to lower energy consumption. RSMA's optimized transmission strategies reduce the need for retransmissions and power-intensive operations, while caching minimizes the frequency of long-distance data transfers. This synergy results in more energy-efficient network operations, contributing to greener and more sustainable wireless communication systems.

ACKNOWLEDGMENT

This research was supported by the MSIT (Ministry of Science and ICT), Korea, under the ITRC(Information Technology Research Center) support programs(IITP-2024-RS-2022-00156353 and IITP-2024-RS-2023-00258639) supervised by the IITP(Institute for Information & Communications Technology Planning & Evaluation).

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