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LARGE INTELLIGENT SURFACE ASSISTED NON-ORTHOGONAL MULTIPLE ACCESS FOR 6G NETWORKS: PERFORMANCE ANALYSIS

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ABSTRACT

Large Intelligent Surfaces (LIS) have emerged as a revolutionary technology for enhancing the performance of 6G wireless networks, offering improved coverage, enhanced spectral efficiency, and better energy utilization. This project focuses on evaluating the performance of LIS-assisted Non-Orthogonal Multiple Access (NOMA) systems, specifically in a downlink scenario where data transmission occurs from the base station (BS) to multiple NOMA users with the help of a LIS composed of multiple reflective elements (REs). The work begins with modeling the end-to-end wireless fading channels between the BS and NOMA users, followed by deriving the probability density function (PDF) of these channels. Using the derived channel statistics, an expression for the pairwise error probability (PEP) is formulated, accounting for the impact of imperfect successive interference cancellation (SIC). Additionally, simplified error probability expressions for scenarios with a single reflective element (M=1) and larger element arrays (M > 10) are provided. The study further analyzes system performance at high signal-to-noise ratios (SNR) and derives asymptotic diversity order along with a tight upper bound for bit error rate (BER). Extensive numerical evaluations and simulations are conducted to validate the proposed analytical framework, demonstrating the effectiveness of LIS in enhancing the reliability and spectral efficiency of NOMA in 6G networks.

Keywords: LIS, SIC, RES, PEP, PDF, 6G, SNR, BER, M value.

I INTRODUCTION

The continuous evolution of wireless communication technologies has led to the development of the sixth generation (6G) networks, which aim to provide ultra-reliable, high-capacity, and low-latency communication. To meet these ambitious goals, innovative technologies such as Large Intelligent Surface (LIS) and Non-Orthogonal Multiple Access (NOMA) have gained significant attention. LIS is a newly emerging concept that employs a surface composed of a large number of programmable reflective elements, capable of dynamically controlling the propagation environment by adjusting phase shifts of incoming signals. This reconfigurable surface enhances coverage, improves spectral and energy efficiency, and facilitates the deployment of advanced wireless communication networks, particularly in dense urban areas and complex propagation environments. NOMA, on the other hand, allows multiple users to share the same time-frequency resources by employing power-domain multiplexing, where different users are assigned distinct power levels based on their channel conditions. This power-domain multiplexing helps to significantly improve spectral efficiency compared to traditional orthogonal access schemes. When combined with LIS, the benefits of both technologies can be harnessed to further enhance signal quality, improve coverage, and increase user capacity in 6G networks. This project investigates the performance of LIS-assisted NOMA systems by analyzing the error rate performance in a downlink transmission scenario, where a Base Station (BS) communicates with multiple NOMA users through the assistance of a large intelligent surface with adjustable reflective elements. The performance analysis considers practical challenges such as imperfect successive interference cancellation (SIC), which is a key process in NOMA for decoding user signals. By evaluating metrics such as Pairwise Error Probability (PEP) and Bit Error Rate (BER), the project aims to provide comprehensive insights into the reliability and efficiency of LIS-NOMA systems under realistic 6G communication environments.

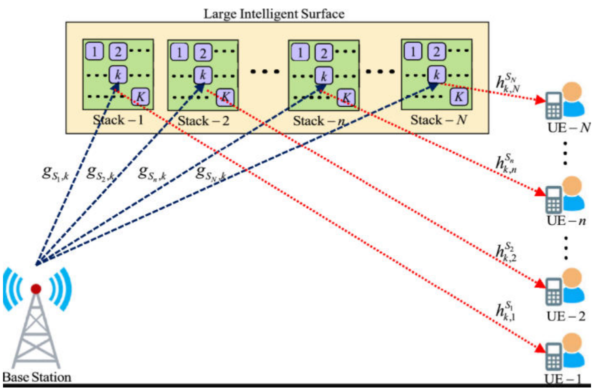

Fig.1. Proposed model.

II.LITERATURE REVIEW

The rapid advancement toward 6G networks has motivated extensive research into novel technologies such as Large Intelligent Surfaces (LIS) and Non-Orthogonal Multiple Access (NOMA) to meet the increasing demand for high spectral efficiency, massive connectivity, and enhanced coverage. Several researchers have explored the role of LIS in next-generation networks due to its unique ability to control wireless propagation environments. Wu and Zhang [1] discussed the fundamental concept of Reconfigurable Intelligent Surfaces (RIS), which are closely related to LIS, highlighting their potential in controlling wave reflection and refraction to enhance spectral efficiency in 6G systems.

Zhang et al. [2] analyzed the combination of LIS and NOMA, demonstrating that LIS can effectively enhance the signal-to-noise ratio (SNR) of weaker users in NOMA transmission by appropriately tuning the phase shifts. This leads to improved fairness and spectral efficiency in multi-user downlink systems. In a similar study, Huang et al. [3] proposed an energy-efficient resource allocation scheme for LIS-assisted NOMA networks, showing that such integration can significantly reduce power consumption while maintaining high system throughput.

Furthermore, research by Basar [4] examined the channel modeling aspects of LIS-aided communications, providing closed-form expressions for end-to-end channel fading and discussing its impact on bit error rate (BER) and outage probability. This work highlighted that accurate channel estimation plays a crucial role in optimizing

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LIS performance, particularly in dense environments typical of 6G networks. In addition to system-level studies, Liu et al. [5] focused on the hardware design and practical deployment challenges of LIS, emphasizing the importance of cost-effective reflective elements and low-complexity phase adjustment algorithms. Their work indicated that while LIS can dramatically enhance spectral efficiency, the performance gains are tightly linked to the accuracy of successive interference cancellation (SIC) in NOMA decoding. Moreover, studies by Ding et al. [6] investigated error rate performance in NOMA systems under imperfect SIC conditions, which is highly relevant to LIS-NOMA integration. They provided analytical frameworks to evaluate pairwise error probability (PEP) and derived asymptotic diversity orders, offering useful performance benchmarks for practical systems. The convergence of LIS and NOMA has also been explored from an optimization perspective, as shown by Guo et al. [7], who proposed joint beamforming and phase shift optimization algorithms to maximize data rates while minimizing error rates. Their results reinforced that large intelligent surfaces can act as passive relay stations, improving both coverage and reliability. This literature review highlights that although extensive research has been conducted on LIS and NOMA individually, the joint performance analysis of LIS-assisted NOMA networks, particularly focusing on error rate performance, is still an evolving area. This project builds upon these existing works by providing closed-form analytical expressions for error performance, considering imperfect SIC, and evaluating the influence of reflective element density in realistic 6G environments.

III.WORKING

The working process of this project focuses on analyzing the error rate performance of a Large Intelligent Surface (LIS) assisted Non-Orthogonal Multiple Access (NOMA) network within the context of 6G communication systems. The system under consideration is a downlink NOMA scenario, where a Base Station (BS) transmits data to multiple users simultaneously. To enhance the communication link, a LIS comprising MM reflective elements is deployed between the BS and the users.

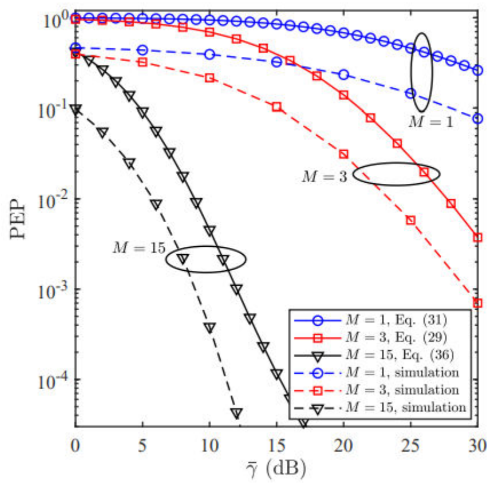

Fig.2. PEP of the first NOMA user, U1, with different numbers of REs.

These elements dynamically adjust their phase shifts to intelligently reflect the incoming signals toward the intended users, thereby enhancing signal strength, especially for cell-edge users with weaker channel conditions. The project workflow begins with mathematical modeling of the end-to-end channel, incorporating the direct BS-to-user link as well as the BS-to-LIS-to-user reflected link. By leveraging statistical channel modeling techniques, the probability density function (PDF) of the combined wireless channel is derived, capturing the impact of small-scale fading and LIS-induced phase shifts. The NOMA scheme is applied at the BS, where different users are assigned different power levels based on their channel conditions, ensuring fairness and high spectral efficiency. To evaluate system performance, the Pairwise Error Probability (PEP) is derived, which quantifies the likelihood of detecting one user's signal incorrectly when another user's signal is already decoded.

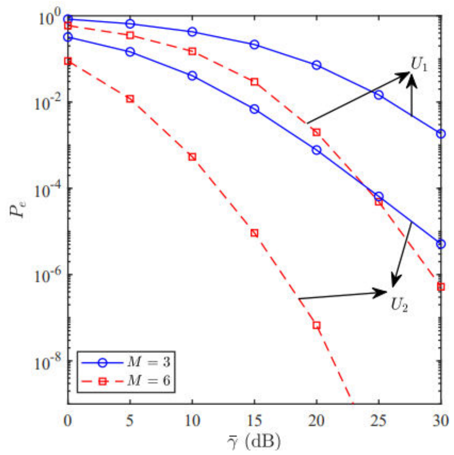

Fig.3. : BER union bound of the two users versus $\bar{\gamma}$ for different number of REs.

A key aspect of the analysis is the consideration of imperfect Successive Interference Cancellation (SIC) at the user end. Imperfect SIC introduces residual interference, which directly impacts error performance. The project derives closed-form expressions for the PEP under both low reflective element count (small M) and high reflective element count (large M) conditions. For the high Signal-to-Noise Ratio (SNR) regime, asymptotic PEP expressions are obtained, along with the corresponding diversity order a critical metric that indicates how quickly the error rate decreases as SNR increases. The analytical results are validated using numerical simulations, comparing the theoretical error rate curves with simulated ones to confirm accuracy. The study also examines the impact of varying key system parameters such as the number of reflective elements (M), number of NOMA users (L), and power allocation factors. By combining mathematical derivations, numerical evaluation, and simulations, the project provides comprehensive insights into how LIS-assisted NOMA systems can enhance spectral efficiency and coverage reliability in future 6G networks, while highlighting the trade-off between performance gains and computational complexity of LIS phase optimization and SIC decoding.

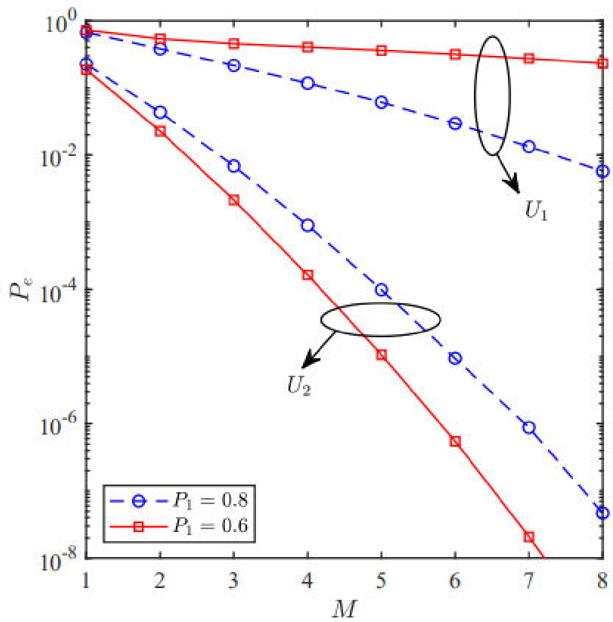

Fig.4. BER union bound of the two users versus M for different power allocation coefficients, and $\bar{\gamma}$ = 15 dB.

IV.CONCLUSION

In this project, we have analyzed the error rate performance of Large Intelligent

Surface (LIS) assisted Non-Orthogonal Multiple Access (NOMA) networks, which form a crucial part of future 6G wireless communication systems. The deployment of LIS with configurable reflective elements significantly enhances the communication link between the Base Station (BS) and multiple users, especially in challenging environments such as urban areas or cell-edge locations. By deriving the probability density function (PDF) of the composite channel and calculating the Pairwise Error Probability (PEP) under both perfect and imperfect successive interference cancellation (SIC), the project offers valuable insights into the interplay between channel estimation accuracy, power allocation strategies, and LIS phase optimization. The results demonstrate that increasing the number of reflective elements (M) improves link reliability and reduces error rates, though at the cost of increased system complexity. The study also confirms that NOMA combined with LIS offers better spectral efficiency and coverage enhancement compared to traditional orthogonal access schemes. Overall, this project highlights the potential of LIS-aided NOMA to become a key enabler for high-capacity, low-latency, and energy-efficient 6G networks. Future work can focus on real-time phase shift optimization algorithms, integration with massive MIMO, and exploring machine learning-based beamforming techniques to further enhance system performance.

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