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Capacity and power allocation optimization in dynamic RIS-enabled mMIMO NOMA systems for 6G

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An innovative approach is proposed to improve capacity performance by including dynamic reconfigurable intelligent surfaces (DRIS) in the downlink (DL) non-orthogonal multiple access (NOMA) power domain (PD) systems with massive multiple-input, multiple-output) (mMIMO) in the setting of 6G wireless networks. To guarantee the system's best performance in different scenarios, we used a unique optimization approach to distribute power among users efficiently using the water-filling algorithm. Analysis of the influence of different deployment densities of static, and DRIS on the performance of the system is presented in this paper. The effect on the effective area spectral efficiency (EASE), and the ability of RIS to reduce latency and handle higher user loads are also discussed. The paper also demonstrates practical 6G configurations, including 256 quadrature amplitude modulation (256-QAM), channel state information (CSI), and successive interference cancellation (SIC). The results indicate that including DRIS in the mMIMO DL NOMA PD system significantly boosts capacity, and EASE while decreasing latency. Implementing logarithmic water filling has proven to be a highly effective method for distributing power location to maximize the capabilities of suggested systems. These results establish crucial information for enhancing future wireless communication systems, and in agreement with the estimated equation, the Monte Carlo results show that our work is accurate and reliable. Integrating the DRIS with four distinct user groups (4, 8, 16, and 32) improves the system's capacity performance by 25%, 25.01%, 25.02%, and 25.03% respectively, compared to the performance conventional static RIS that applied in other related works.

Keywords: NOMA, massive MIMO, Reconfigurable Intelligent Surfaces (RIS), Effective Area Spectral Efficiency (EASE)

1 Introduction

Ultra-high reliability, wide-coverage, massive connectivity, enhanced privacy, unprecedented spectrum efficiency, outstanding power efficiency, and explosive data rates are all features of sixth-generation (6G) mobile communications technology [1-4]. The current advancement is facing unprecedented challenges caused by the limited availability of radio resources for cellular communications [5, 6] and the primary quandary stems from the swift proliferation and advancement of wireless gadgets.

Cellular networks have found great success with massive multiple-input multiple-output (mMIMO) technology, which increases both network throughput and energy efficiency [7-8]. Furthermore, a huge gain in variety is achieved by efficiently allocating time-frequency resources to different users by employing spatial resources, also, very mMIMO communications are better in high-path propagation situations than in low-frequency bands [10]. Even though mMIMO improves spectrum utilization, it necessitates expensive hardware, wide deployment, and complex implementation. In the future, wireless networks will be unable to utilize mm wave communications because of the substantial scattering, diffraction, and penetration loss [11, 12]. These factors result in exceptionally high leakage rates for continuous transmission progress.

Using overlay power domain (PD) and optimizing spectrum density, non-orthogonal multiple access (NOMA) allows service to numerous users inside a single resource block and successive interference cancellation (SIC), as demonstrated in [13-17]. Assigning different users to the same frequency band in a way that minimizes interference and maximizes data transmission efficiency is a major challenge in wireless communications [18].

Prior studies have demonstrated that NOMA uses superposition coding to accommodate numerous users inside a single resource block. NOMA employs sequential interference removal, which can result in the accumulation of errors and a loss in performance when the channel state information (CSI) is inaccurate [19] and [20].

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Among the several benefits that reconfigurable intelligent surfaces (RISs) have offered to the area of advanced communication systems in recent years are the ability to construct intelligent radio environments and cost-effectiveness [21, 22]. Their ability to change the communication channel and atmosphere in a way that is both functional and environmentally beneficial has caught the interest of many users.

The RIS have unique electromagnetic properties, such as the ability to absorb waves, change their phase precisely, and reflect them in unique ways and the goal is to lessen the bad effects of a natural wireless environment [23, 24]. The RIS distinguishes itself from other technologies by its ability to customize the radio waves that purposely strike it, allowing it to perform functions that are not naturally present in materials found in nature. Luckily, the RIS design can be put into action by making use of the specific traits outlined in [25, 26], without the need for complex signal processing, interference management, or specialized encoding and decoding techniques. The two primary classifications of RIS artificial surfaces are meta-surfaces and antenna arrays. The flat surface consists of three levels, each equipped with its controller [27].

1.1 Passive and dynamic RIS

A common method for controlling RISs as opposed to passive reflect arrays is by employing extremely fast field programmable gate array circuits. It is possible to customize the RIS and communicate with the base station (BS) with these add-ons. Importantly, each component's reflection coefficient can be adjusted to suit the challenging propagation conditions.

RIS are categorized as either passive, intelligent, or dynamic based on their capacity to respond and adapt to their wireless surroundings. The configuration, including phase shifts, of the static RIS remains constant and is unaffected by external factors or signal circumstances. DRISs can respond to wireless network signals or changes in their surrounding environment by dynamically adjusting their phase shifts.

At regular intervals, a centralized controller tweaks the RIS parameters to enhance the signal quality for users. It adapts to the user's movement around the network and any changes to the CSI. It is constantly adjusting to the ever-changing conditions of the network, the position of the user, and the CSI. In response to extremely dynamic situations, such as those with great mobility (e.g., users in cars), or abrupt changes in interference or impediments, a DRIS allows for fast, continuous, or adaptive changes in the surface layout, expanding the concept of intelligent RIS. In response to sudden shifts in its surroundings, it not only adjusts in real time but does it more quickly than before. Nevertheless, in multi-user settings in particular, the ever-changing character of wireless networks calls for sophisticated tactics for the effective distribution and division of RIS methods.

A solution to the problem of interference caused by multiple users has been suggested, rate splitting [28, 29]. Comparing rate division to both NOMA and conventional broadcast, the study finds that it performs better. The methods of rate division, as detailed in References [30] and [31], have been employed in earlier research.

When signal-to-noise ratios (SNR) are high, rate splitting improves spectral efficiency (SE) more than normal broadcasting [31, 32], and NOMA [34]. However, the authors neglected to consider inter-connected channels and incomplete CSI. Rate splitting improves the transmission throughput and versatility of mMIMO systems. Optimal integration of NOMA and RIS enables flexible modification of channel conditions for users. A major limitation of RIS-enhanced wireless networks is the difficulty in guaranteeing QoS for distant users. This is because RISs attached to building facades can only provide services to users in specific geographic locations [33].

Compared to passive RIS, dynamic also called active RIS frequently shows significant performance gains, according to empirical research (shown in Figure 1). However these advantages come with higher power bills, which goes against the sustainability idea of RIS's low power usage and cost-effectiveness. A dependable power source is still required for the revolutionary energy-efficient architecture introduced in [34, 35] to deliver greater power than passive RIS. Energy harvesting technology has quickly become our go-to for DRIS power supply problems, thanks to the meteoric rise of green energy in the last several years and the advantageous locations of RIS installation sites.

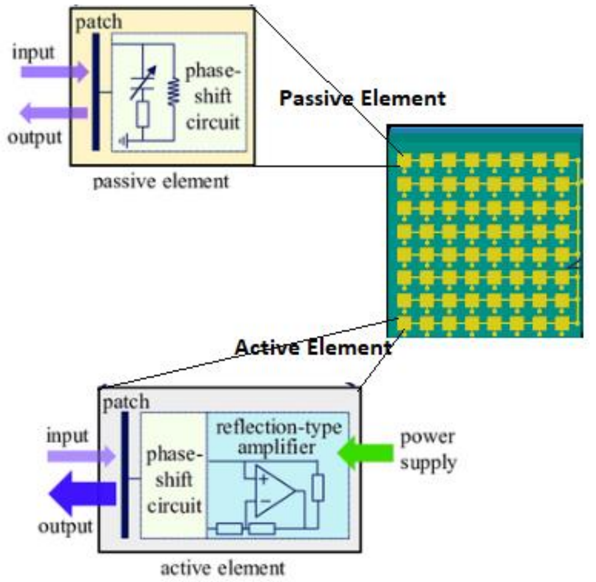

Fig. 1. Comparison between passive and dynamic RIS elements

1.2 Research contribution

This work presents a novel strategy to enhance system performance by integrating DRIS into the DL NOMA PD system with mMIMO in the context of 6G wireless networks. RIS is a very promising technology that has not yet been fully investigated, especially when combined with NOMA and mMIMO. An interesting strategy is the dynamic adaptation of RIS according to real-time channel circumstances and user distribution. However, most previous research concentrates on static RIS setups.

Within the scope of this study, the scalability of the system is evaluated by the rise in the number of users and the SNR levels. Given that NOMA is specifically engineered to accommodate several users with varying channel characteristics, it is essential to comprehend the influence of these parameters on capacity. Although the interference and non-orthogonal sharing of resources pose barriers, it is crucial and difficult to properly manage resources and allocate energy in NOMA systems. A water-filling optimization logarithm is proposed in this paper to address the issue of power allocation and improve the performance of the system. More specifically, we have documented the most significant contributions made by our work:

- An integrated system concept is presented, that combines mMIMO NOMA with and without DRIS-assisted devices. This integration aims to improve the efficiency of spectrum and power allocation in 6G networks by boosting signal quality.
- A novel approach was presented to enhance the phase shift of the RIS, therefore enabling dynamic regulation of the system. An objective is to amplify the signal intensity and raise the capacity of the suggested system. The optimization study considers both the direct channel and the reflected channel that is supported by DRIS.
- Investigated the impact of different user densities (4, 8, 16, and 32 users) on the capacity of the hybrid system. It provides insights into how the system performance improves with increasing user demands in the NOMA-enabled mMIMO 6G network, both with and without DRIS. The analysis shows that using DRIS significantly improves capacity. By improving both signal quality and system throughput, DRIS demonstrates its indispensability as a fundamental element of future networks.
- Employed a novel optimization strategy to effectively distribute power among users, both with and without DRIS, using the water-filling algorithm. Using these optimization strategies, you may be certain that the system will operate at its best in any given situation.
- Through an investigation of the impact of DRIS on latency and user load in a mMIMO-NOMA system, and an analysis of the relation between system performance, effective area spectral efficiency (EASE), and total network efficiency as a function of different deployment densities of passive, and DRIS. this study demonstrates that DRIS has the capability to decrease latency and manage increased user loads in upcoming 6G networks.
- In order to ensure the applicability of the results to actual 6G networks, an assessment of the model's performance is conducted utilizing actual circumstances and scenarios., including 256-QAM and 24 GHz bandwidth. This study includes a comprehensive analysis of user distribution and a specific path loss model.

The reminder of the paper is organized as follow: Section 2, presents the closed and important related works. Section 3, discussed the proposed system’s mathematical model. Section 4, presents the Simulation results and discussion. Finally, the conclusions and future works were discussed in section 5.

2 Related works

A rate-division strategy for RIS-supported mMIMO networks is proposed. This method improves spectral efficiency (SE), eliminates user interference, and improves obstruction-affected coverage. By using statistical channel state information, the author may calculate the total rate and reduce signal overhead. Simulations show that the RS approach enhances the rate more than the broadcast strategy [36]. The analysis focuses on emerging paradigms of AI-driven RIS systems, encompassing their conceptualization, implementation, and progress. Research is also being conducted to explore the incorporation of emerging technologies to improve RIS application and deployment performance. Energy use, safeguarding transport, and the process of making something more contemporary [37]. AI-Driven [RIS] Reference [37] is specifically on rate-splitting multiple access (RSMA) on wireless backhaul heterogenous network (HetNets) which may provide light to RIS. Concretely, the specific decentralized strategy investigated in [37] may be recapitulated with distributed AI solutions for RIS optimization. As shown, the focus differs, but works such as signal splitting and superposition coding from RSMA might be useful if one has to design for RIS environments.

The study [38] investigated the topic of robust beamforming design for NOMA communication systems, assisted by RIS while keeping factor CSI in mind. The numerical results demonstrate the method's efficacy. RIS BER performance with the NOMA and constellation approaches was mathematically evaluated, assuming receiver detectors. The RIS-NOMA constellation technique outperformed the standard RIS with NOMA without the constellation technique. The analytical results and computer simulations matched well [39].

About RIS-NOMA and energy-efficient setups in beamforming communications are indeed enlightening. Thus, by identifying concerns such as signal attenuation and coverage gap, they help direct future researchers in achieving more effective and efficient methods of beamforming. These may enhance the broadband, disaster management, and IoT services that has an overall bearing on the beamforming transmission growth.

The efficiency of NOMA vehicle networks is investigated using RIS to determine the effect of insufficient cascade interference cancellation. Ultimately, the analysis is corroborated by Monte Carlo and numerical simulations [40]. The NOMA system, using RIS to broadcast and reflect signals, was examined for economical pricing. This is important when obstacles prevent direct BS-cell edge user communication, but RIS allows line-of-sight. Get precise formulas for edge-of-cell user work rates and SNR slopes. Systems that directly transmit data and networks that decode and transmit Nakagami-m fading channels both showed an improvement in the observed EASE. The ergodic capacity and average impacted area were calculated using a closed-form formula for the maximum transmit power range. SE as measured by EASE is then presented [41].

Use RISs with directional antennas to examine narrow-beam millimetre wave network connections. Leakage theory determines how many nodes are needed for connectivity. Since the RISs are located outside of the transmission footprint, where the signal is weak and requires boosting, this is very necessary. The outcomes show that the RIS network setup was affordable [42]. Table 1 summarizes limitations of related works.

Table 1. Summarization of related works

[36]	I/O hardware limitations and complexity in PS optimization; It is rarely possible to assume ideal channel characteristics.
[37]	Performance aspects of the mixed-integer non-convex optimization problem; Sensitivity to the deep learning model's accuracy and transferability.
[38]	This reduced system performance due to imperfect CSI; phase shifters with low resolution cause quantization.
[40]	Multi-dimensional objectives may be met suboptimally. A very high level of complexity arises when attempting to coordinate beamforming across multicell networks.
[41]	Mobility and changes in the environment they operate within in reference to the channels; Interference and effective resource management in NOMA-D2D.
[42]	Transmissive RIS cannot be deployed in complex, hostile environments Heterogeneous and complex hardware Platforms assumed to be connected to other platforms do not necessarily enjoy such connectivity.

Reconfigurable Intelligent Surfaces (RIS) are anticipated to be integrated in 6G system adopting wireless channels proactively [43]. These studies focused on power consumption, particularly that of the RIS, and reconfiguration delay and note that addresses these problems for realistic deployment. This research suggests a new RIS design that uses integrated circuits with MOS varactor loadings for low power consumption and high frequency operation with accurate phase shifter control. In [46] it proves the advantage of RIS in promoting WPT efficiency through adapting transmitter power and RIS phase map. In [47] and [48] both present related work on the integration of RIS with the CR system where authors discuss how the integration of RIS with CR will further enhance the efficiency of spectrum utilization by improving the spectrum sensing capacity and efficient utilization of resources.

3 System model

Consider the system depicted in Figure 2 depicts the mMIMO DL NOMA PD wireless network with k users, each equipped with N_r receive antennas. Please consider this system. According to NOMA's power allocation technique, users with weaker channels are given more power, and users with stronger channels are given less power. The N_t transmit antennas installed on the BS create the mMIMO configuration. The NOMA functionality allows users to be multiplexed in the power domain. With this function, various users can share the same frequency and time resources by assigning them varying degrees of power.

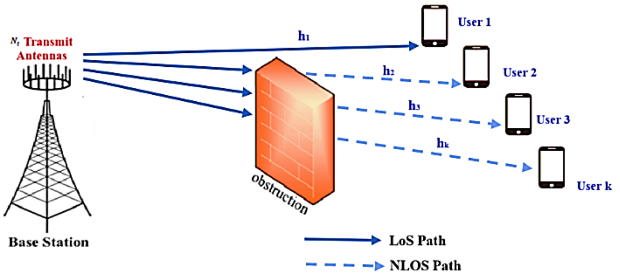

Fig. 2. mMIMO PD DL NOMA with *k* users

The BS in NOMA sends a superposition of signals on all users. The sent signal x is,

$$x = \sum_{k=1}^{K} w_k x_k \tag{1}$$

User k's beamforming vector is denoted as $w_k \in \mathbb{C}^{N_t \times 1}$. x_k is the data symbol representing user k, and the set $\mathbb{E}[|x_k|^2] = 1$. The wireless channel model includes LoS and NLOS paths. Smaller-scale fading, path loss, and noise affect the BS-user channel. The mMIMO system involves K users communicating with the BS that has M antennas. This is the channel matrix H that connects the BS to the users,

$$H = [h_1, h_2, \ldots, h_K] \in \mathbb{C}^{M \times K} \tag{2}$$

$h_k \in \mathbb{C}^{1 \times N_t}$, this channel vector h_k connects the BS and user directly, independent of any support from the DRIS. User k received the signal,

$$y_k = h_k x + n_k \tag{3}$$

$$y_k = h_k w_k x_k + \sum_{j=1, j \neq k}^{K} h_k w_j x_j + n_k \tag{4}$$

3.1 Dynamic RIS (DRIS)

In DRIS, both the amplitude and phase shifts of the incoming signal are managed. The digital surface in DRIS features a reflective configuration using Positive Intrinsic Negative (PIN) diodes. By applying specific control voltages to individual PIN diodes, the reflection coefficients of the surface elements can be manipulated dynamically to achieve discrete phase or amplitude states. With additional controlled variables, designers can leverage greater flexibility in their designs. As a result, enhanced performance can be attained. However, a notable drawback of this category is the significant increase in complexity.

The system illustrated in Figure 3 exhibits the integration of the DRIS technique with the proposed system. N reflecting elements make up the DRIS. Each element reflects the incident amplified and phase shift signals, which improves the overall channel conditions.

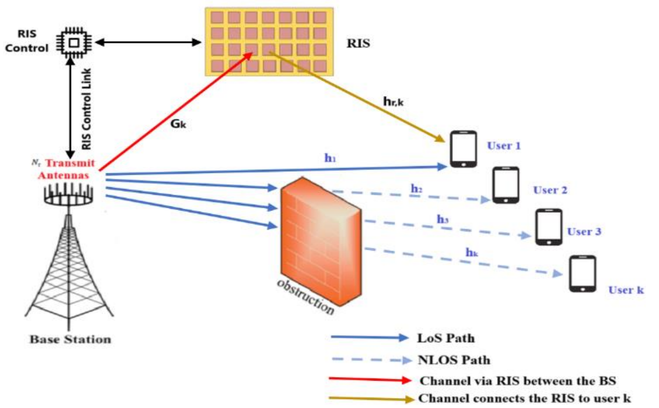

Fig. 3. mMIMO PD DL NOMA with *k* users with DRIS technique

3.2 DRIS channel model

The wireless environment can be dynamically managed with the help of the DRIS, which provides an extra reflected link between the base station and users. The DRIS's phase shifts are regulated by a matrix $\Theta = diag(e^{j\theta_1}, e^{j\theta_2}, \ldots, e^{j\theta_N})$, the phase shift that the nth element applies is represented by θ_n and it be adjusted in such a way that it is possible to increase the received SNR by constructively combining the signals.

The channel between the BS and user k in DRIS includes both the direct and reflected paths through the platform. The BS and users have direct and indirect channels $h_k \in \mathbb{C}^{M \times K}$, $G_k \in \mathbb{C}^{M \times N_t}$, and $h_{r,k} \in \mathbb{C}^{N \times K}$, where N is the number of DRIS elements.

The overall effective channel for user k in the system assisted by the DRIS is determined by,

$$h_k^{RIS} = h_k + h_{r,k} \Theta G_k \tag{5}$$

This expression incorporates the direct connection h_k as well as the DRIS-assisted reflected link $h_{r,k} \Theta G_k$.

$$y_k^{RIS} = h_k^{RIS} x + n_k \tag{6}$$

$$y_k^{RIS} = (h_k + h_{r,k} \Theta G_k) w_k x_k + \sum_{j=1, j \neq k}^{K} (h_k + h_{r,k} \Theta G_k) w_j x_j + n_k \tag{7}$$

Here, the DRIS creates an additional reflected link that boosts the overall channel gain. The user $k's$ SINR in the mMIMO NOMA system without DRIS is

$$SINR_k = P_k |h_k w_k|^2 / \sum_{j=1, j \neq k}^{K} P_j |h_k w_j|^2 + \sigma^2 \tag{8}$$

For user k, the SINR with DRIS is

$$SINR_k^{RIS} = P_k \left|h_k^{RIS} w_k\right|^2 / \sum_{j=1, j \neq k}^{K} P_j \left|h_k^{RIS} w_j\right|^2 + \sigma^2 \tag{9}$$

Power allocated to user k is indicated as P_k.

$$P = \sum_{k=1}^{K} P_k, P_1 > P_2 > \cdots > P_K \tag{10}$$

The PD technique is used by NOMA to distribute the entire power P across users. The strongest user receives P_K and the weakest P_1.

The RIS control system optimizes phase shifts Θ to enhance user experience by maximizing SINR or capacity. Consumers suffer more constructive interference when phase shifts θ_n are adjusted to synchronize reflected signals. The phase shifts Θ_{optim}must be determined to optimize SINR or system capacity.

$$\Theta_{\text{optim}} = \underset{\Theta}{argmax} \sum_{k=1}^{K} \log_2\left(1 + SINR_k^{RIS}\right) \tag{11}$$

System configuration includes K users for this analysis. B represents the entire frequency range. H_k is the kth user's channel gain. Total power delivered by the transceiver is denoted by P_{total}, N_0 represents noise power spectral density. The matrix $\Gamma_k = |H_k|^2 P_k / N_0 B$ represents the SNR for user k.

User capacity is calculated by adding their power to channel gain. To maximize system performance, distribute power location efficiently among users.

$$C_k = B \log_2(1 + |H_k|^2 P_k / N_0 B) \tag{12}$$

The $k - th$ user's power is P_k, while its capacity is C_k. When all the users' capacities are added together, the result is,

$$C_{\text{total}} = \sum_{k=1}^{K} C_k = \sum_{k=1}^{K} B \log_2(1 + |H_k|^2 P_k / N_0 B) \tag{13}$$

The objective is to maximize capacity by efficiently utilizing the total power, P_{total}, across K users.

$$\underset{P_k}{max} \sum_{k=1}^{K} (1 + |H_k|^2 P_k / N_0 B) \tag{14}$$

According to,

$$\sum_{k=1}^{K} P_k \leq P_{\text{total}} \tag{15}$$

where $P_k \geq 0$, $\forall k$

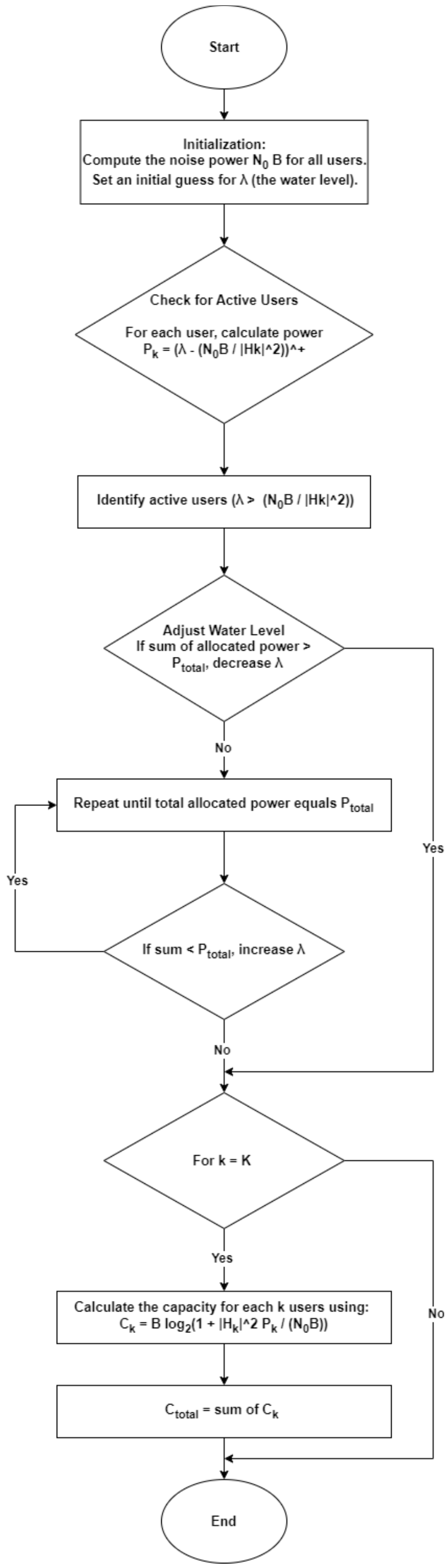

Fig. 4. Optimal capacity utilization with Water-filling power allocation flowchart fir DRIS

Optimizing P_{total} distribution across users is crucial for optimal capacity. As shown in Fig. 4, a water-filling method distributes power more efficiently to consumers with higher channel gains $|H_k|^2$. Users' channels are represented in water-filling by an inverse channel gain of $\frac{1}{|H_k|^2}$ in this container and user power allocation depends on the channel power level. Based on mathematical concepts, the water-filling algorithm distributes power to users based on water level λ. To ensure valid use, users should only receive positive power $(x)^+ = max(x, 0)$.

$$\sum_{k=1}^{K}(\lambda - N_0 B/|H_k|^2)^+ = P_{total} \quad (16)$$

A measure of the channel gain that results from using DRIS during transmission is the DRIS phase shift matrix, Θ.

$$\left|H_k^{RIS}\right|^2 = |H_k + H_{RIS}\Theta H_{BS-RIS}|^2 \quad (17)$$

The direct channel gain of BS-user k is denoted by H_k. The channel gain matrix for DRIS users is expressed as H_{RIS}. The BS-RIS channel gain matrix is marked as H_{BS-RIS}. The DRIS achieves optimal signal reflection by utilizing the phase shift matrix Θ.

At this point, we must optimize the process of expanding total capacity by locating the optimal DRIS phase shift matrix and the power allocation P_k that is the most efficient.

$$\max_{P_{k,\Theta}} \sum_{k=1}^{K} B \log_2\left(1 + \left|H_k^{RIS}\right|^2 P_k/N_0 B\right) \quad (18)$$

Mathematical models often express RIS deployment density ρ as a dimensionless percentage between zero and 1. A lower density ($\rho \approx 0.1$) suggests sparse RIS deployment, while a greater density ($\rho \approx 1$) indicates dense deployment. The capacity of the system is inversely related to the latency and number of users in the system.

Using the EASE metric is one way to determine how effectively a communication system utilizes the spectrum that is accessible in a particular region. A network performance evaluation is necessary in situations where there are a large number of users, such as in 6G networks. It is common practice to write the EASE formula as follows,

$$EASE = SE/d^2 \quad (19)$$

The transmitter-receiver distance is d meters.

The EASE equations for the system with various RIS settings are as follows,

$$EASE_{\text{no RIS}} = \log_2(QAM) \cdot BW/K \cdot d^4 \quad (20)$$

$$EASE_{\text{passive RIS}} = \log_2(QAM)BW(1 + 0.5 \cdot \rho)/K \cdot d^4 \quad (21)$$

$$EASE_{\text{dynamic RIS}} = \log_2(QAM)BW(1 + 1.5 \cdot \rho)/Kd^4 \quad (22)$$

K is the system's user count. In high-frequency transmission, distance is intensified to the fourth power (d^4) to account for excessive path loss.

4 Simulation results and discussion

Presented in Tab. 2 are the simulation parameters of the mMIMO DL NOMA PD systems model in 6G networks. The figures illustrate the relationship between the scalability of these systems and the growth in the number of users, SNR, capacity rate. The charts provide a comparison of results obtained with and without the installation of DRIS, latency under different user loads and densities, and EASE versus RIS deployment density.

Figure 5 shows the relationship between capacity rate and SNR for four sets (4, 8, 16, and 32) of mMIMO DL NOMA PD users, considering varied distances and power locations inside the 6G network. Capacity rate and SNR were positively correlated. The capacity rate of the 4 users is 10.1211 Gbps/Hz, the capacity rate of the 8 users is 5.6054 Gbps/Hz, the capacity rate of the 16 users is 2.8027 Gbps/Hz, and the capacity rate of the 32 users is 1.4014 Gbps/Hz with the SNR of 30 dB.

Table 2. Presents the technical specifications of the simulators utilized to system model networks

Parameter	Value
Users Groups No.	4, 8, 16 and 32
Modulations	256 QAM
Path-loss exp.	4
BW	5 GHz
mMIMO	128×128
DRIS	512×512
SNR	0 to 30 dB

Integrating the DRIS with four distinct user groups (4, 8, 16, and 32) improves the system's capacity performance by 25%, 25.01%, 25.02%, and 25.03% respectively, compared to the performance without DRIS. The final result was superior to the results obtained in [43-44]. Specifically, the results suggest that the improvements in capacity are directly correlated with the user count. The DRIS is able to improve signal reflections, resulting in more efficient utilization of the wireless environment. In addition, larger user groups benefit from significantly greater interference management, increased multi-user variety, and superior beamforming. Hence, the system's performance improves positively with the growth in the user count.

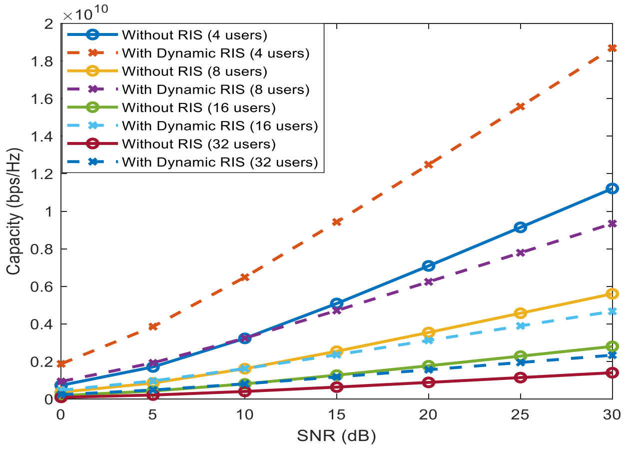

Fig. 5. Capacity vs. SNR for 4 different groups mMIMO DL NOMA users with and without DRIS

Four groups (4, 8, 16, and 32) of mMIMO DL NOMA PD users are shown in Fig. 6. The groups are distributed over distinct distances and power locations within the 6G network. The plot illustrates the correlation between capacity rate and SNR for these groupings using the suggested logarithm. SNR correlated positively with capacity rate. At the SNR of 30 dB, the capacity rate for the 4 users is 43.99 Gbps/Hz, the capacity rate for the 8 users is 39.86 Gbps/Hz, the capacity rate for the 16 users is 34.89 Gbps/Hz, and the capacity rate for the 32 users is 29.94 Gbps/Hz.

The capacity of the system and the performance are raised by 12%, 13%, 14%, and 16%, respectively, when four distinct user groups are included in the DRIS (4, 8, 16, and 32). This compares system performance without the DRIS. The end outcome was better than what was found in [45, 46]. The suggested algorithm greatly enhances capacity performance using the DRIS system, as shown by the results. The performance improvement is directly proportional to the growth in users, improved resource allocation, and more effective utilization of DRIS components. The scalability analysis is indeed a perfect means of proving the link between the number of users and system capabilities. technically, yet have certain concepts that need to be better elucidated in terms of the actual implementation of such systems although better when it comes to density, or varying mobility generated by users.

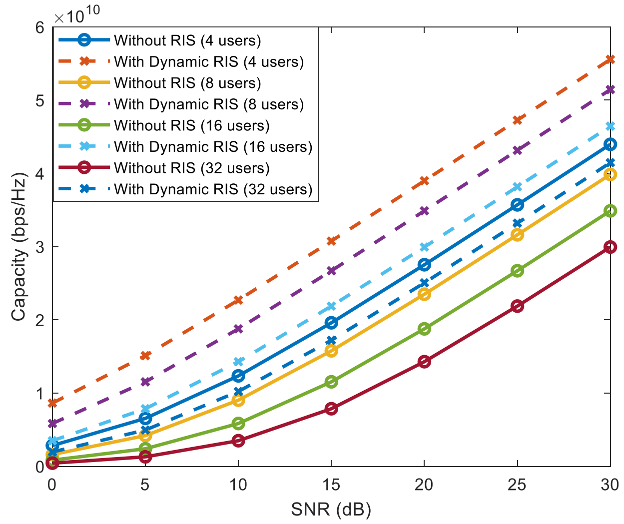

Fig. 6. Capacity rate against SNR for 4 groups with water-filling power allocation algorithm of mMIMO DL NOMA users with and without DRIS scheme

The relation between latency and user load is illustrated in Figure 7 for 6G network users of mMIMO PD DL NOMA with and without DRIS. In two cases when the data shows that latency grows with user load. Systems that utilized DRIS exhibited noticeably reduced latency in comparison to those that did not, with an improvement of 43% at a user load of 30. Adjusting DRIS phase shifts dynamically in response to user needs and external events leads to better utilization of available BW and fewer transmission delays.

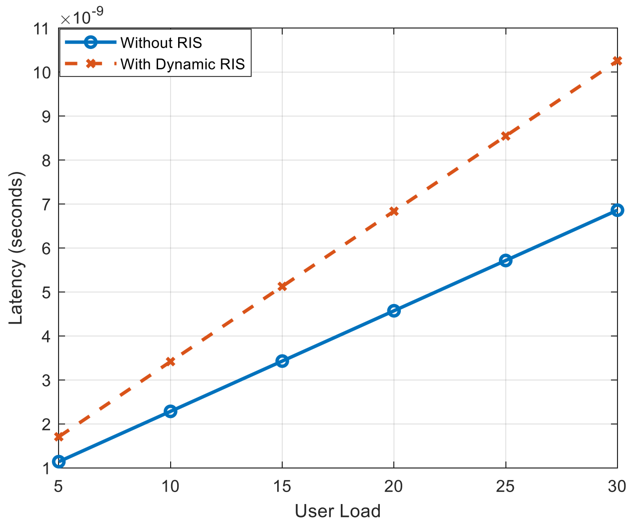

Fig. 7. Latency against user load for mMIMO DL NOMA users with and without DRIS technology

Figure 8 shows that for 32 mMIMO PD DL NOMA users, there is a correlation between EASE and the deployment density of RIS. This association holds for passive, and DRIS in the 6G network. Regardless of the scenario, the results show that EASE grows in tandem with RIS deployment density. The EASE without using RIS is 11354.24 bits/Hz/m^2, passive RIS leads to a 20% performance boost, and DRIS leads to a 42.8% enhancement at the RIS deployment density of 1. Based on these results, RIS may be able to overcome spectral and spatial constraints in congested network situations.

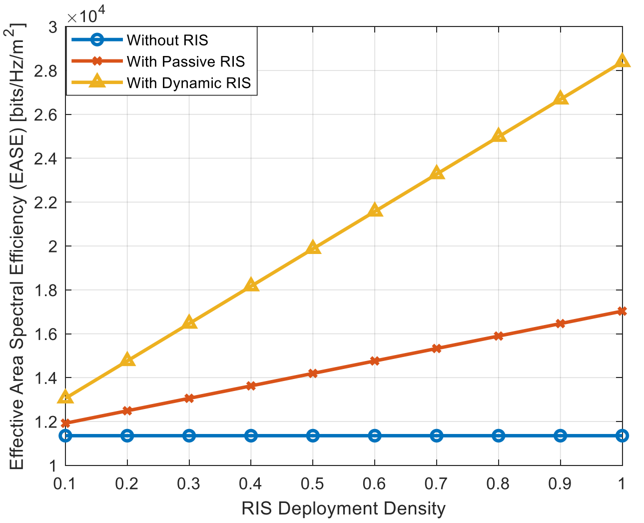

Fig. 8. EASE vs. RIS deployment density for 32 mMIMO DL NOMA users with and without (passive, and dynamic) RIS scheme

While the use of Dynamic RIS greatly decreases latency, it causes additional overhead. This overhead is in terms of control signaling, additional computation required, and limitations in hardware to perform phase adjustments on the signal. Measuring this overhead is essential to properly determine overall system effectiveness and to fine-tune assorted mobile RIS applications.

5 Conclusion

To achieve the high capacity, and low latency needed for 6G networks, this study shows that mMIMO-NOMA systems integrated with DRIS offer a promising solution in a novel method. The study demonstrates significant gains in capacity, when compared to conventional systems lacking DRIS, all thanks to the use of DRIS phase shift optimization. DRIS technology is well-suited to congested situations because of its excellent latency performance, interference management capabilities, and user fairness enhancements. The optimization considers modifying phase shifts using CSI.

To make the most of NOMA systems, water-filling is a great way to distribute power locations to users who have stronger channels used innovatively. The system's capacity is greatly improved with the addition of RIS, which allows for the dynamic enhancement of channel gains. An effective approach to optimizing DRIS phase shifts and power allocation together maximizes the performance of proposal systems in 6G networks.

In this work, we enhance the current knowledge of 6G network implementation by investigating the influence of RIS integration on the design of mMIMO NOMA systems. The main findings show that RIS significantly improves EASE and SE, especially in dynamic systems, when compared to passive RIS or without RIS. The result helps in making enabling ultra dense networks, supporting high speed mobility, and reduction of energy consumption, all of which are vital for the success of 6G.

In addition to highlighting the importance of RIS distribution density, the results provide practical suggestions for improved RIS placement in future network installations including 256- QAM, CSI, and SIC with different power locations, distances, and SNR, so ensuring the relevance of the results to upcoming 6G networks. Integrating the DRIS with four distinct user groups of 4, 8, 16, and 32 enhance the network capacity by 25%, 25.01%, 25.02%, and 25.03% respectively, compared to the performance conventional passive RIS that applied in other closed related works. While the use of Dynamic RIS greatly decreases latency it causes additional overhead, in our future research will focus on it. This overhead is in terms of control signaling, additional computation required, and limitations in hardware to perform phase adjustments on the signal. Measuring this overhead is essential to properly determine overall system effectiveness and to fine-tune assorted mobile RIS applications.

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