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# Sum Rate Maximization for Irregular Reconfigurable Intelligent Surface (RIS) Using Reinforcement Learning

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**Abstract:** Reconfigurable Intelligent Surfaces (RIS) is an innovative technology in telecommunications systems that use artificial and programmable surfaces to manage radio waves and optimize communication environments. This technology is particularly relevant in 5G and 6G systems as a tool to improve signal quality, reduce interference, and increase the capacity of communication systems. The signal-to-noise ratio (SNR) is very important in radar target detection. In this research, Reinforcement Learning Method used to optimize irregular reconfigurable intelligent surface. The reward function is optimized by adjusting the phase parameters of the arrays and pre-coding vectors. The reconfigurable intelligent surface is considered as irregular arrays. The method presented in this study is based on Sum rate Maximization. Reinforcement learning is used to find the optimal location of antennas. The results indicate the superiority of reinforcement learning over Tabu Optimization and greedy search methods.

**Keywords:** Radar-Communication Dual-Function System, 6th Generation, Reconfigurable Intelligent Surfaces, Data Rate, Sum Rate Maximization, Optimization, Reinforcement Learning

## Introduction

Signals in high-spectrum bands, such as millimeter-wave spectrum and terahertz frequencies, can easily be obstructed by blockages. Reconfigurable Intelligent Surfaces (RIS) can enhance communication between the source and the destination. In a Multi- antenna transmit single-receive wireless system, where there is an smart surface to assist communications through multiple antennas (APs) to a single-user antenna, the signal transmitted from the user is directly received by the antenna. The IRS independently adjusts the beamforming and phase, changing alternately until convergence is reached. The beamforming and reflection of the reconfigurable intelligent surface (RIS) are used for radar sensing and single-user radar communications, where the Signal-to-Noise Ratio (SNR) serves as a functional metric. The system, which serves both sensing and communication (ISAC), alleviates multi-hop fading, and the RIS itself is a semi-sensing sensor that is configured for sensor networks. To solve the intricate non-linear optimization challenge, a dual-layer solution based on concave-convex optimization is proposed. The algorithm's constraints are Second-Order Cone Programming (SOC), which is used to address the non-convexity in hybrid beamforming. The integrated radar- communication system, assisted by a smart reflection surface (IRS), is a scenario with single radar target with multiple users. The objective is to optimally maximize the weight between the radar and target matrix by designing IRS precoding weights.

Reconfigurable Intelligent Surfaces (RIS) is a recent technology in the wireless communication ecosystem, and it becomes an object of greater academic interest, especially when applied to the next-generation 5G and 6G.

RIS entities are able to self-effect communications in deploying programmable artificial surfaces, and thus making possible optimization of data transmission processes.

A wide range of benefits granted by RIS provides the testimony to the role that it plays as one of the most instrumental technologies to enhance the performance and efficiency of wireless systems.

The main benefit of RIS is quite high reduction of on-equipment expenses and energy, as compared to traditional active signal amplification systems.

Amplification scheme in normal communication system can require the introduction of power amplifiers and other active circuits which typically involve a high level of energy consumption and often involve high financial expenses. However, RIS, using smart surfaces that only require digital adjustments, can modify radio waves indirectly without the need for power amplifiers. This feature reduces operational costs and significantly lowers energy consumption.

RIS is a good way to expand the communication facilities. By modifying the signal paths and forcing them to the relevant receivers, RIS has the ability to avoid interference and improve signals to receivers. Besides, with accurate control of the phase and strength of radio waves, weak signals can be enhanced and the quality of communication increased by RIS. The latter aspect is especially handy in limited conditions such as congested networks. Signal interference is one of the primary problems to which communication systems in busy environments are vulnerable because such settings are very crowded and usually busy. Physical barrier, other radio signals and even nearby radar and communication systems can be the cause of interference. RIS is capable of solving the problem of interference and routing the signals to receivers in an efficient layout by adjusting the signal trails. This improves the quality of received signal and minimization of error. Moreover, appropriate conditions of network, like radar and communication interference may be adjusted to using RIS and negativeness of these interference will be reduced. Weak signals and poor coverage are one of the fundamental issues in the communicational systems especially in the places which are remote or so high. When faced with this kind of situation, RIS would enable a better quality of communication. RIS is able to direct signals in nearby routes, and remaining reflections and scaling, so giving superior coverage in low efficiency locations, or areas of obstructions. This has been a special feature of communication systems whose coverage has to be larger. Intelligent tools like RIS would allow customizing the wireless environment to make the best use of the associated communication conditions as well as enhance the quality of a link between the base wireless stations and user devices. As an example, in urban conditions with sky-scraping structures with numerous obstructions, RIS is able to bend radio waves and penetrate all-blocking objects to transmit improved signals to the distress. This adaptability will ensure that the 5G and 6G dynamics can deal with more complicated settings. The other benefit associated with RIS is its compatibility with other communication and radar system. In particular, in the communication networks containing radar and communication system having joint frequencies.

Reconfigurable Intelligible Surfaces (RIS) is used to isolate the interference systems of the heterogeneous systems through modulating signal reflections and through the optimization of both the transmission-as well as reception paths to ensure the performance of the radar as well as the communication subsystems. The facility cannot be done without in terms of defense, surveillance, and commercial sectors and uses where conjoining these systems are the most important. Such as power amplifier analogs, RIS needs minimal more bulky infrastructure. In addition, RIS is inherently reconfigurable and flexural in nature with easy and contagible surfaces enabling easy installation and deployment. Moreover, RIS is very unlikely to demand significant energy usage making the technology less costly than others. Therefore, RIS is even more cost-effective, in terms of large-scale scale implementations in multiple settings.

Reconfigurable Intelligent Surfaces are a newer concept of wireless communications, having complementary improvement in performance through the regulated adoption or screening of electromagnetic waves. The most common conventional RIS designs are lattice structured in collaboration, making it exceptionally easier to use when compared to irregular structured forms and, as a result, used in the settings with low variability significantly more often. Irregular RIS designs typically use straightforward optimization algorithms than those applied to conformable ones due to the computational saving associated with the harmonized way they are organized. Examples of representative algorithm are:

Gradient Descent Algorithms which are often used to derive optimum set of RIS parameters including phase shifts, amplitude of reflection; a systematic distribution of standard RIS elements can make these algorithms be able to work.

The Genetic Algorithms (GA) which could be used in knowing the optimal distribution and location of RIS elements particularly in the circumstance where optimization problems are in play are continuing to be used.

Alternating Optimization Algorithms are applied in order to get complex optimization problems to change the many variables needed in the RIS, it is the best adaption algorithm when the position of elements needs to be changed and signal reflections need re-calibration.

The algorithms of Neural Networks -based processing; in some cases, machine learning and neural networks are used to refine network configurations and signal reflections on their own.

Modelling signal propagation within the RIS environment is critical in a usual context. This kind of modeling would emulate the existence of signals under different conditions and signal needed characteristics used to be modified to fit according to conditions simulated by the model. The mathematical descriptions of phenomena such as the Rayleigh and Rician models are often used to realize the attributes of the environment.

Phase and amplitude of returned signals have to be optimally added to the system to optimize the performance of a wireless network in conventional RIS. These have to be done by optimization algorithms, which generally redirect the reflected signals to desired receivers.

In irregular RIS the elements are either systematically arranged within the surface or randomly, or complexly, randomly distributed across the surface. This geometrical imbalance is especially beneficial in dynamically thereabouts motion which represent heterogeneous construction.

The main aim in an irregular RIS design is to provide a high signal quality where the environment is biased towards the high defects of interference and noise to provide better coverage and performance as compared with the typical RIS barbaric. The method is particularly useful in city environments that are characterized by tall-rise buildings, complex barriers, and wireless signal blockages. The irregular RIS would need careful layout of several key aspects: whereas in regular RIS all the elements would be aligned on a grid form, the layout of the irregular RIS would be based on a stochastic or complex pattern. Such a construction extends more flexibility to the designers to have package environmental variations. The calculations of the exact spatial arrangement of every element which will result in optimum signal improvement and elimination of interference could be accomplished with the help of optimization algorithms. Results in changes in element structure lead to an alteration in the reflection of signals as well as their phase and strength. Thus, reflective attributes; especially, the phase and amplitude have to be controlled and properly governed to attain maximum system functioning.

Very advanced phase-control and optimization algorithms allow architects to bend bounced back signals in a direction with regard to targeted receivers. The irregular RIS should quickly confront changes in the environment, and thus the design should managed to provide dynamic and real-time responses to reconfigure and optimize itself. In this regard, the optimization algorithms should be in a position to perform instantaneous changes in RIS surface layout and configuration and in effect maximize the overall system performance.

The control of irregular reconfigurable intelligent surfaces (RIS) requires a complicated set of optimization tools where the system is dynamically adjusted in formulation and in parameters. In irregular RIS design it is irreplaceable with the specific modeling of the reflective signal characteristics at various levels. Such models have to know how to adapt to the irregular geometry and physical heterogeneity of the surrounding environment obstacles, walls and scattering areas. To this extent, our stochastic models include Rayleigh fading and Rician fading which are used to faithfully model signal dynamics as it goes through different propagation channels and interfaces with different surfaces.

Such careful management of very properties of reflection as phase angles, signal amplitude, andangular orientations is crucial in irregular RIS systems. Some strategies that could be drawn are optimization schemes that could help to reduce interference, widen the coverage area, or increase the signal intensity in specific territories. Most contemporary communication studies file the use of Additive White Gaussian Noise (AWGN), because of the unbiased nature of noise against frequency, which makes it (AWGN) more appropriate to model a inflation of noise representing the base level noise with respect to signal transmission. In architectures based on RIS, AWGN is able to deteriorate the quality of signal reception and deaden the Signal to Noise Ratio (SNR). RIS can compensate the detrimental impact of AWGN by proper correction of phase shifts and amplification of reflected components and boost the SNR and increase overall communication performance. As a result, it causes a direct effect on SNR of the system indeed, when it is low, the received signal amplitude falls sharply and the error rate of the bits increases significantly. The reflective state could be also engineered using RIS to improve the signal received and in turn increase the SNR.

In the case of communication systems that are RIS-improved, AWGN is an important factor that dictates signal integrity. However, it is found that strategic placement of RIS can alleviate system performance in a system running with the occurrence of this noise source. The negative effect of the AWGN can be reduced through accurate modulation of the RIS surface and the navigation of the propagation paths, which in turn drops the level of wireless communication.

The research is based on the new methodology that is grounded in the area of reinforcement learning.

## Related works

In (Weidong et al, 2022) Intelligent Reflective Surface (IRS) have emerged as a prospective method for cellular networks. IRS enables flexible control and configuration of wireless channels, significantly enhancing wireless signal transmission rates and reliability. In the design and optimization of various wireless systems aided by IRS, prior studies have mainly aimed at enhancing wireless links by reflecting a signal with one or more IRS panals, which may be inadequate to increase wireless link capacity under some severe channel environments. This issue can be addressed by using two or more IRSs to assist each radio channel and jointly exploit their wave propagation paths on the link.

In (Yishi et al, 2022), applications of Intelligent Transportation Systems (ITS) and autonomous driving in the 6G era greatly depend on extensive information exchange requiring widespread data sharing, great dependability, and minimal delay to secure safety and experience. On the other hand, waves in elevated frequency such as millimeter wave and T-rays can be readily obstructed by obstacles. To address this problem, IRS has attracted considerable interest as it can bounce back signals. IRS is acknowledged as a promising technology for terrestrial and airborne networks to enhance signal strength, lower-level security, and positioning accuracy. This paper provides a in-deapth survey of study advancement on various IRS applications in terrestrial and airborne vehicle communications. In (Ozgecan et al, 2019), smart reflecting surfaces can improve transmission between the source and receiver. The panel includes metamaterials configured to "revert" incoming waves from the provider toward the intended. Two conflicting path loss models have been used in previous works. We derive the far-field path using material optics techniques and explain why the surface consists of many elements, which singly act as scattered scatterers but can together beamform the signal in a desired direction with a particular beamwidth. In (Ruochen et al, 2023), IRS is expected to have many applications in future wireless networks. latent elements bounce the incident signal. This paper examines a multi-input point-to-point IRS system in a single-output (MISO) wireless system where an IRS supports communications via a multi-antenna node to a single-antenna user. Consequently, the AP simultaneously receives the user signal directly. We first propose a centralized algorithm to improve semi-definite relaxation (SDR) assuming global channel conditions, where the IRS requires excessive centralization for over-performance. The IRS independently adjusts beamforming and phase iteratively until convergence. In (Honghao et al, 2022), this paper proposes a joint design of transmit beamforming and reconfigurable intelligent surface S\N (abbreviation) reflection for radar detection and single-user communication, using radar (SNR) as a performance metric. In (Shuang et al, 2024), a adaptable ismart surface (RIS) integrated into a mm-wave system is used in incorporated sensing and communication (ISAC) to alleviate multi-relay fading. RIS is semi-sensing and arranged in sensor layouts to receive echo radar signals with concentrated angular direction estimation precision, obtained from the Cramér-Rao Bound (CRB) sensing metric. The Fisher Information Matrix (FIM) addresses the non-convex problem using a two-layer concave-convex algorithm. Algorithm constraints include consecutive convex approximation (SCA) and second-order cone (SOC), addressing hybrid beamforming non-convexity. The proposed CRB algorithm shows that sensing performance can reach about 96% of fully digital approaches with less RF chains. In (Xiang et al, 2020), a novel dual-function radar communication (DFRC) design assisted by IRS is proposed, involving a scenario with one aim and various communication sensors. Radar pre-coding matrix and IRS weights are refind to amplify balanced efficiency between radar and target. SNR at communication receivers is prone to power and fixed factor limitations on IRS weights, separated into two components: waveform configuration and IRS weight blueprint. The latter is resolved via quadratic improvement, while the first one uses linear programming. The key contribution lies in IRS weight design through quadratic optimization.

In (Ziwei et al, 2024), DFRC technology is rising in next-generation wireless systems, with reconfigurable intelligent surfaces (RIS) as a key sensor component. This paper studies a multi-input multi-output (MIMO) DFRC system aided by a hybrid RIS (HRIS), capable of reflecting communication signals to mobile users and simultaneously receiving reflected scattering signals from radar targets. Beamforming vectors at the base station (BS) and HRIS configuration parameters are optimized to maximize signal-to-interference-plus-noise ratio (SINR). A non-convex beamforming design problem is solved by the fast gradient search with accelerated gradient descent (FGS_AGD) algorithm to find the best HRIS configuration.

In (Eyad et al, 2023), beyond enhancing communication performance, IRSs are promising enablers for intelligent reflecting surfaces to achieve larger sensing coverage and higher-quality sensors. IRSs also facilitate beam sensing or target information analysis. A wireless system containing a multi-antenna BS and an IRS jointly optimized for target detection and IRS phase shifts is proposed, with three new detection methods:

1. Time Division (TD) Sensing
2. Signature Sequence (SS) Sensing
3. Blended TD_SS Sensing for flexible balancing between beam pattern gain and sensing efficiency.

By controlling group numbers, hybrid TD_SS sensors offer a more flexible balance between beam pattern enhancement and dual-layer frequency sensing.

In [10], with improved 5G standardization, 6G performance and emerging key features can be envisioned. The Radio Access Network (RAN) enables dense deployment and cellular infrastructure to build a perceptive network. This involves integrated sensing and communication (ISAC) applications with advanced sensing and communication approaches. ISAC performance is analyzed, highlighting trade-offs from information theory limits to physical layer design and multi-layer signal design. ISAC processing aspects, including waveform design and signal processing, are discussed as steps toward deeper integration of communication and sensing functions within perceptive networks. This includes aided communications or sensing, their technologies, and positive impacts on future wireless networks. Considering the overall trend of next-generation communication systems, most technologies have shifted towards higher frequencies, especially the Millimeter waves

band. However, many existing radar systems, such as air traffic control, geophysical measuring and monitoring systems, weather monitoring, and military based operations, still work in the sub-6 GHz band. This spectrum sharing results in mutual interference between radar and communication systems, posing challenges in joint design and harmonious coexistence (Rubinstein et al, 2013) (Mahal et al, 2017). In this regard, reference (Li et al, 2016) proposed a method based on Matrix Completion (MC), where MIMO radar and communication systems are jointly examined. In this model, a fusion center estimates the interference caused by the radar signal at the communication receivers and then removes it from the received signal. Despite the advantages of this approach, its performance decreases under high radar transmit power or phase variations among system components and cannot completely eliminate residual interference. In (Grossi et al, 2020), MIMO radar and MIMO communication systems sharing a common frequency source were studied. The authors designed joint precoding matrices for radar and communication transmitters such that, while maximizing common data and signal quality metric at the radar receiver, constraints on signal clarity, power, and transmission speed were also met. The outcomes show that a radar-beneficial precoder can reduce the interference at the communication receiver units (ComUTs) through reducing signal cooperation at the same time, increased the signal-to-interference plus noise ratio, (SINR) at the radar receiver. Reference (Cui et al, 2017) proposes a strategy to control cause of interference between radar and a coexisting system of communication which is an interference-alignment-based approach to managing the interference. In this scheme, an optimization problem is created whose goal is to achieve maximum SINR of the radar and communication subsystem by detention jointly of (precoders and decoders) jointly increasing the arrival of cross-system interaction.

In reference, (Qian et al, 2018), the covariance of the transmitted communication signal and the radar signal is optimised in such a way that the covariance of the application of the transmitted communication system maximises the data rate that is achievable despite energy restrictions. The resultant design is also known to produce very high spectral efficiency in shared environments without disrupting the radar functionality. A main building block of fifth-generation (5G) and other various technologies, millimetre-wave (Millimeter wave) communications can be used to provide wide bandwidths and provide a bit higher than a gigabit rates of data transmission, but are extremely vulnerable to blockage as well as being heavily affected by rainfall and other environmental issues, thus making their implementation challenging. Most of these means of shortcoming have been addressed by introducing reconfigurable intelligent surfaces (RIS); surfaces with capabilities to intelligently rearrange the propagation environment and providing a new degree of freedom in wireless system design. These surfaces cause a modulation of a phase of the reflected waves without requiring radio-frequency chains or complicated processing to combine them properly on desired propagation paths and build constructive or destructive delays off-peak, with the result that communication quality is significantly enhanced in challenging environments. Cooperation of communication and the sensing in a common spectrum which minimizes the interference and maximizes spectral factor is seen as a desirable development in the technology as well as the industry (Ma et al, 2020).

two operative paradigms in integrated sensing and communication (ISAC) researchRadar-communication coexistence (CRC) and dual-function radar-communication Radar communications Represent two radically different paradigms within the coupled sensing and communication (ISAC) research domain. CRC aims at ensuring the harmonization of both joint operations on the shared spectrum without the two systems relying on each other in terms of hardware in any way (Zheng et al, 2019) (Petropulu & Trappe, 2016). Contrarily, the DFRC systems place spectral and hardware efficiency enhancement AIDS functionality and communication capabilities covert between one unified system, instead of deconstructing them in separate systems (Liu et al, 2020), which significantly improve power consumption cutback (Liu et al, 2020) (Hassanien et al, 2015). A critical issue during the implementation of a working DFRC systems is the ability to design appropriate waveforms. The literature generally divides this challenge into three groups (Zhou et al, 2022) communication-centric signals design (CCWD) (Sturm & Wiesbeck, 2011) (Liyanaarachchi et al, 2021) (Zeng et al, 2020) (Wu et al, 2021), detection centric signals design (SCWD) (Xie et al, 2021) (Nowak et al, 2016) (Wang & Xu et al, 2022), and joint waveform optimization and design (JWOD) (Liu et al, 2020). The main goal of CCWD is to adapt conventional transmission signals, such as conventional communication formats and Orthogonal Time Frequency Space (OTFS), to have specific sensing capabilities. In particular, these adapted signals can derive detection data from reflections. nevertheless, owing to the stochastic nature of transmission signals, perception performance may be seriously impacted. In contrast to CCWD, SCWD aims to design detection signals in a way that the adapted signal also has data transfer abilities. transmission information can generally be embedded in perception signals; for example, embedding communication signals in the spatial domain to realize SCWD (Yang et al, 2020). Although embedding communication symbols in radar signals is simple and straightforward, the low data rate associated with this method is a significant limitation, restricting its use to specific scenarios. Additionally, the lack of practical demodulation principles poses a challenge in utilizing embedded communication information. Unlike CCWD and SCWD, JWOD does not alter current communication or radar signal shapes but designs new signals based on real situations with greater flexibility. Generally, the new signals have higher number of independent, enabling a symmetry between transmission and sensing performance. In (Dong et al, 2023), a beam pattern configuration for multi-user DFRC systems was presented, showing that proper radar waveform design can raise DoF used for target sensing. DFRC system efficiency can be significantly degraded by challenging propagation settings with signal blockage, particularly for target detection. Fortunately, RIS can solve this problem by actively shaping the propagation environment while maintaining reduced resource and hardware expense (Wu & Zhang, 2019). RIS typically consists of numerous inexpensive passive elements, each capable of independently adjusting the phase of the incoming signal [35][36]. The major advantages of RIS, such as expanding range and enhancing dependability, have been broadly demonstrated (Pan et al, 2022).

The application of RIS in other communication fields encouraged researchers to combine it with DFRC systems. Initially, RIS was used solely to improve communication performance, while sensing tasks relied on direct transmitter–receiver–target links (Zhu et al, 2022) (Wang et al, 2021). In (Zhu et al, 2022), an RIS-assisted ISAC system was studied, including an ISAC base station, multiple targets, and communication users (CUs). RIS was used to create a reliable BS-RIS-CU link and improve signal strength in the communication coverage area. Authors in [40] also studied an RIS-assisted ISAC system where a dual base station served multiple CUs and sensing targets simultaneously, while RIS was used only to aid communication and reduce multi-user interference (MUI). However, in urban environments, surrounding buildings often block the BS–target path. To further utilize RIS benefits, especially in improving radar sensing performance, RIS is also used to create a virtual link between BS and target. In (Jiang et al, 2021), RIS was deployed near the BS, which served a single-antenna CU while detecting targets. In this case, radar signal-to-noise ratio (SNR) was maximized while maintaining CU-related SNR constraints. later, authors in (Song et al, 2022) extended this scenario to multi-target sensing under non-line-of-sight (NLoS) conditions, where the BS simultaneously served a solitary-antenna CU and maximized the least beamforming radiation pattern toward targets while keeping BS power and CU SNR constraints. A comparable case was considered in (Li & Petropulu, 2022), where a paired BS concurrently detected a sole target and served multiple CUs with RIS enabled.

In contrast to previous (Song et al, 2022)and Li & Petropulu, 2022) that focused on specific scenarios without direct BS-target links (Zhang, 2022) and (Luo et al, 2023) examined more general applications involving multiple targets and multiple CUs. In [44], a joint optimization problem of mutual information (MI) for sensing and sum data rate for communication was studied. In this work, beamforming and phase shift matrices were alternately optimized under BS transmit power constraints. Conversely, [45] focused on enhancing target detection performance while ensuring performance level requirements for communication users and overall transmit power budget constraints.

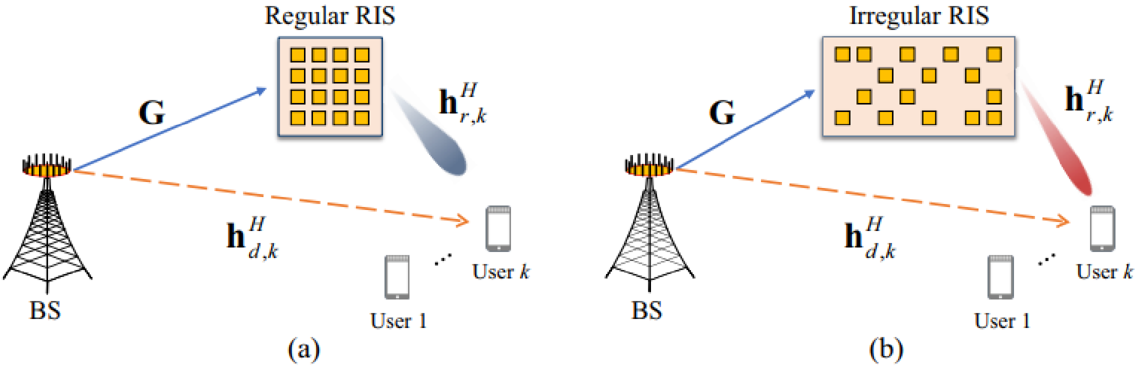

**Figure 1.** The RIS-based communication system: (a) The standard regular RIS. (b) The new irregular RIS.

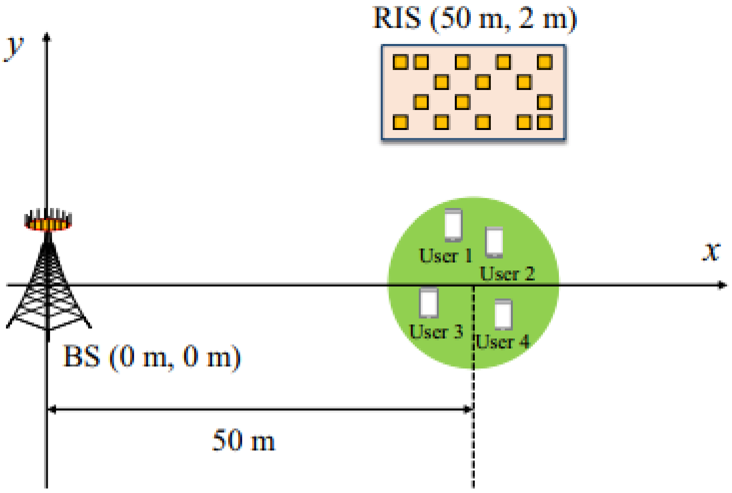

**Figure 2.** The computational model of the suggested method with irregular RIS enabled communication system

In Figure 1. The RIS-based network: (a) The traditional regular RIS. (b) The suggested irregular RIS presented. In Figure 2. It has the simulation scenario of the proposed irregular RIS aided transmission system.

## Methodology

Various salient issues and limitations arise in the context of the design of irregular reconfigurable intelligent surfaces (RIS). Of primary importance here are the high level of computation in the task. The implementation of advanced optimization aids and the needed high-performance computing capabilities which are required to accurately model electromagnetic reflections, elements positioning, and phase modulation place a great load on the design process. These computation needs can only be magnified by the terms that the number of elements that make up the RIS is large or there are many configuration states that have to be taken into account.

Lacking regular propagation situations Often show elevated, randomly varying fluctuations, such as obstruction of cellular operations, changing network conditions and transforming signalling paths. In this point, an RIS architecture should also show enough dynamism to respond speedily to such perturbations and to re-tune its operational parameters. In addition, the complex design approach that surrounds irregular RIS increases the financial resources that would go into deployment, maintenance and integration of system. Such an increase in cost will be a significant impediment to wide adoption, particularly to large scale deployments.

Another obstacle is because it involves advanced methodologies of optimization in managing the many functionalities of an RIS. These approaches have to simulate and optimize element locations and reflected wavefronts skillfully even in highly complex, time-varying furnishings. With irregular RIS conditions the characteristics of the signals and any obstructions can change at random and hence the system is prone to uncertainties such as additive noise as well as dynamical network behaviour which can severely impair performance.

### Reinforcement Learning

Reinforcement Learning is a one of machine learning methods where an **agent** learns how to make decisions by **environment interations**. The agent takes actions, observes the outcomes, and receives rewards or penalties based on those actions. Over time, it learns a policy—a strategy of which action to take in each state—to maximize cumulative rewards.

Optimization is the process of finding the best solution (maximizing or minimizing a function) from a set of possible options. Traditional optimization methods often rely on gradients or heuristic rules and sometimes struggle in complex or dynamic environments.

The current status or configuration of the irregular array is state of RF. Moving antenna to empty neighbours is action and reward is the Value of Sum Rate.The strategy the agent learns to decide which action to take at each state.

The agent chooses an action, observes the resulting state, and receives a reward.

Using algorithms like Q-learning, policy gradients, or actor-critic methods, the agent updates its strategy to maximize cumulative rewards (i.e., find the best solutions).

The agent’s goal is not just to maximize the immediate reward but to maximize the **expected cumulative reward** over time:

$\gamma$ determines how much the agent **values future rewards** compared to immediate rewards.

If $\gamma$=0, the agent is **myopic** and cares only about immediate rewards.

If $\gamma$ is near to 1, the agent values long-term rewards almost as much as immediate ones.

Helps ensure the sum converges when rewards continue indefinitely.

Summary: Reward Equation in RL is calculated as below:

$$r_t = R(s_t, a_t)$$

**Total expected discounted reward (return) is**

$$G_t = r_t + \gamma r_{t+1} + \gamma^2 r_{t+2} + \cdots = \sum_{k=0}^{\infty} \gamma^k r_{t+k}$$

## Result and Discussion

After implementation of RF with irregular RIS the following results extracted. In Figure. 3. The perfected RIS topology with N = 32, Ns = 64 configuration presented. In Figure. 4. The perfected RIS topology with N = 32, Ns = 64 configuration presented. In Figure. 5. The perfected RIS topology with N = 32, Ns = 64 configuration presented. In Figure. 6. WSR and the number of RIS component compared. Transmission output is 10 dBm, Ns is 120 and K equal to 4. In Figure. 7. WSR and the number of RIS components compared. Transmit Power is 10 dBm, Ns is 120 and K equal to 4. In Figure. 8. WSR and the number of RIS elements compared. Transmit Power is 10 dBm, Ns = 120,and K is 4. In Figure. 9. WSR and the number of RIS elements compared. Transmit Power is 10 dBm, Ns = 120 and K = 4.

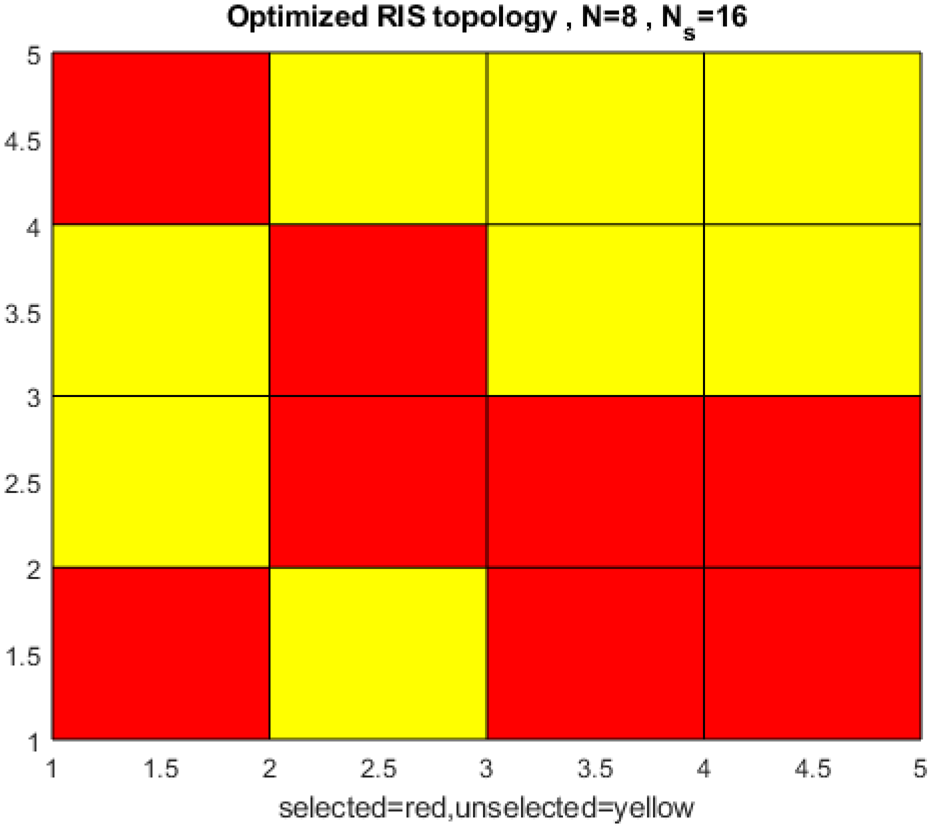

**Figure 3.** The optimized RIS topology. Ns = 64, N = 32

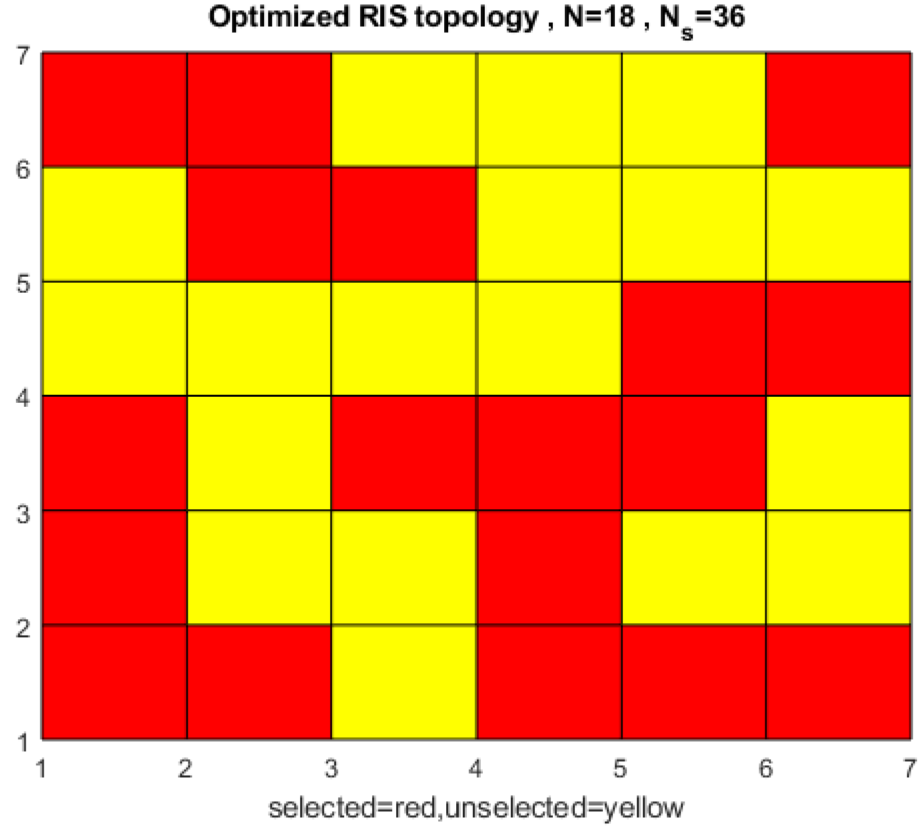

**Figure 4.** The optimized RIS topology. Ns = 64, N = 32

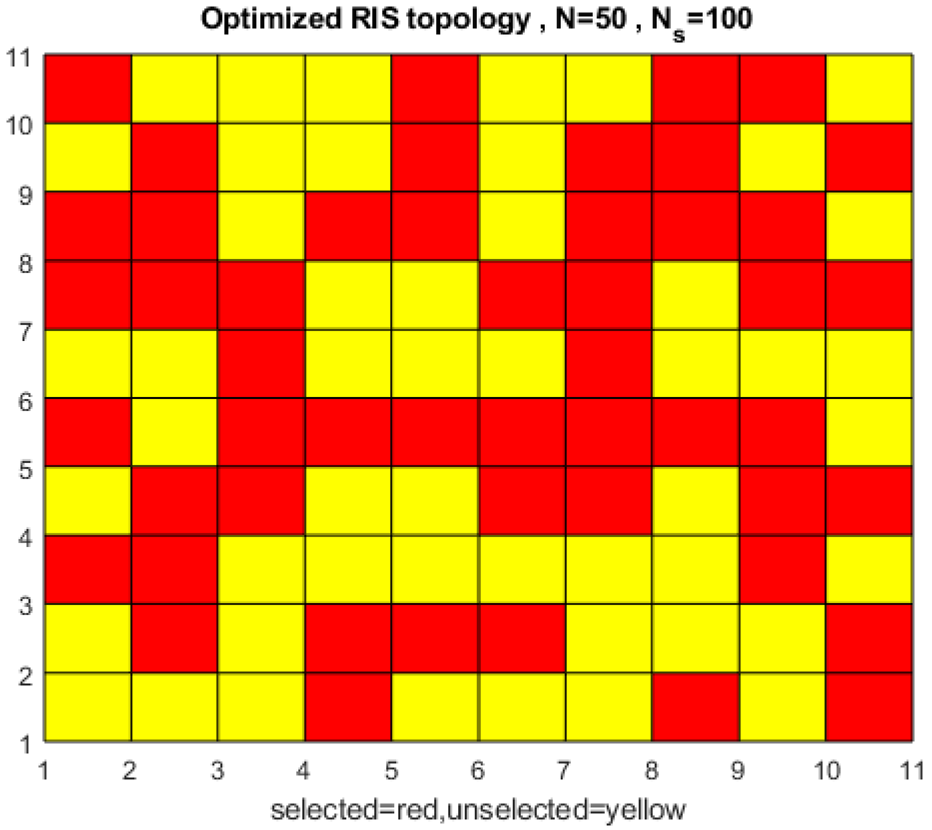

**Figure 5.** The optimized RIS topology.Ns = 64, N = 32

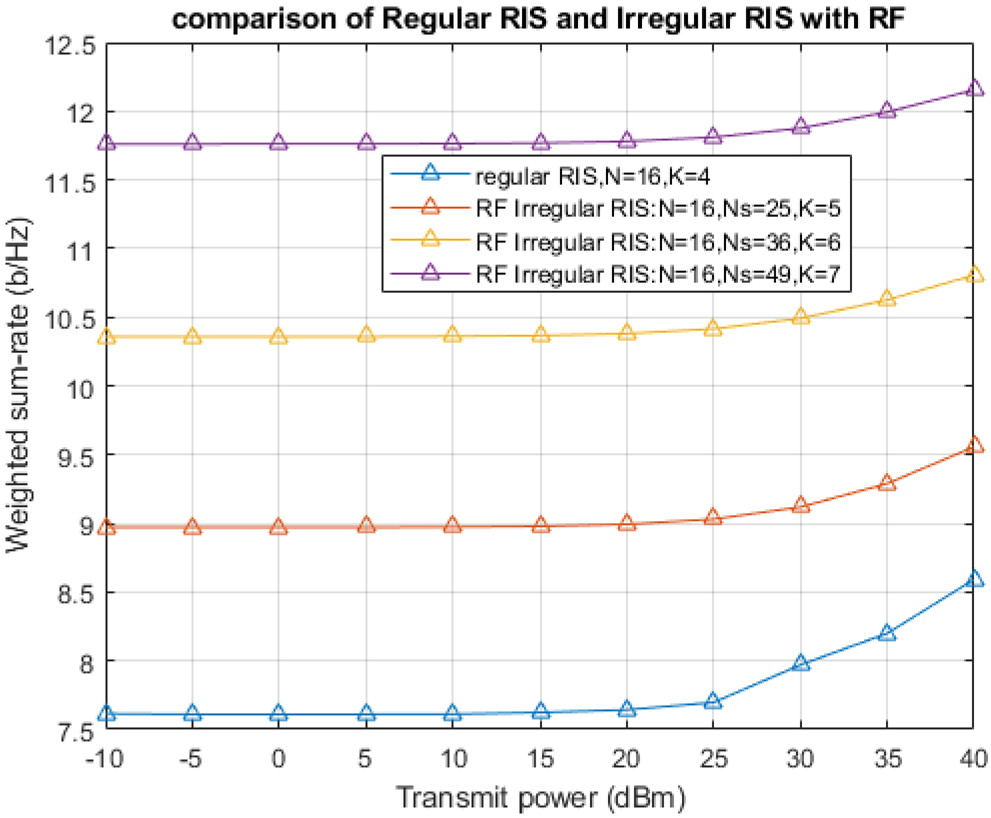

**Figure 6.** Comparing WSR and the number of RIS elements. Transmit Power = 10 dBm, K = 4, Ns = 120

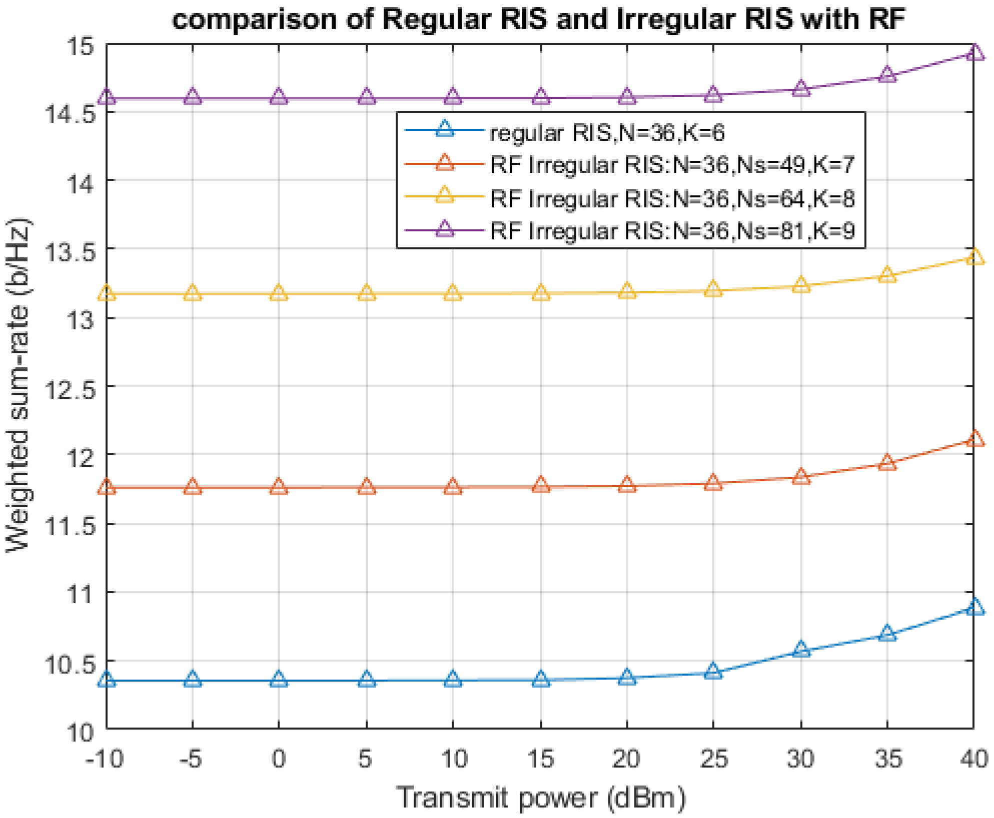

**Figure 7.** Comparing WSR and the number of RIS elements. Transmit Power = 10 dBm, K = 4, Ns = 120

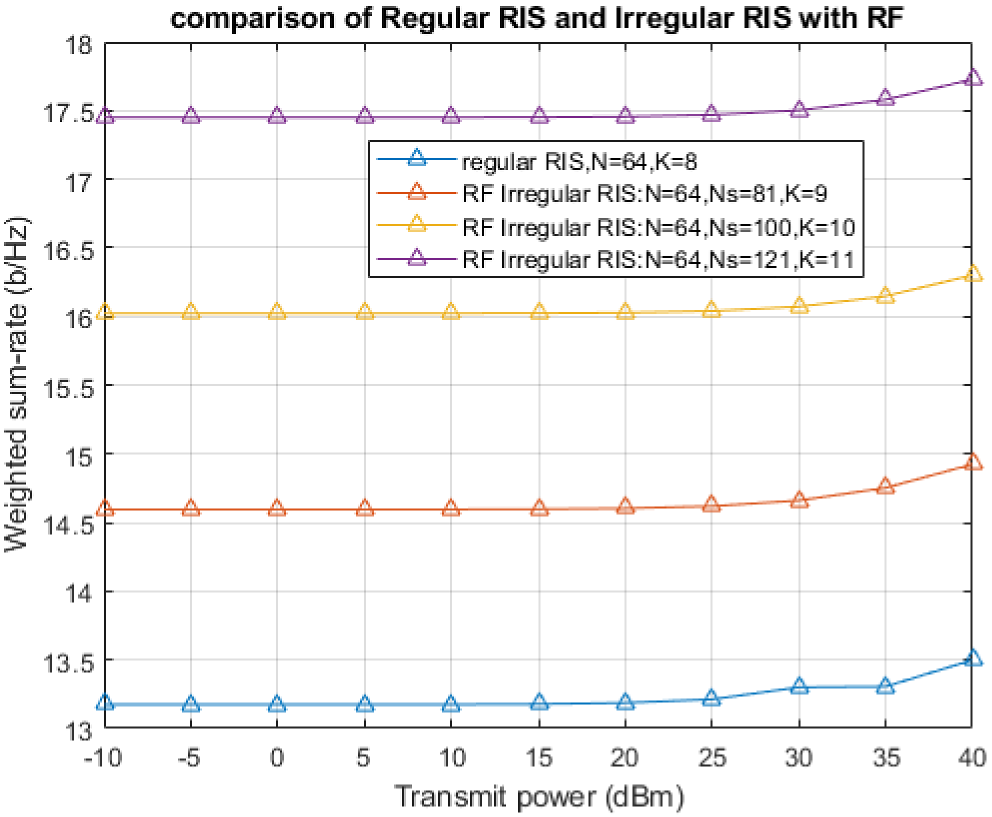

**Figure 8.** Comparing WSR and the number of RIS elements. Transmit Power = 10 dBm, K = 4, Ns = 120

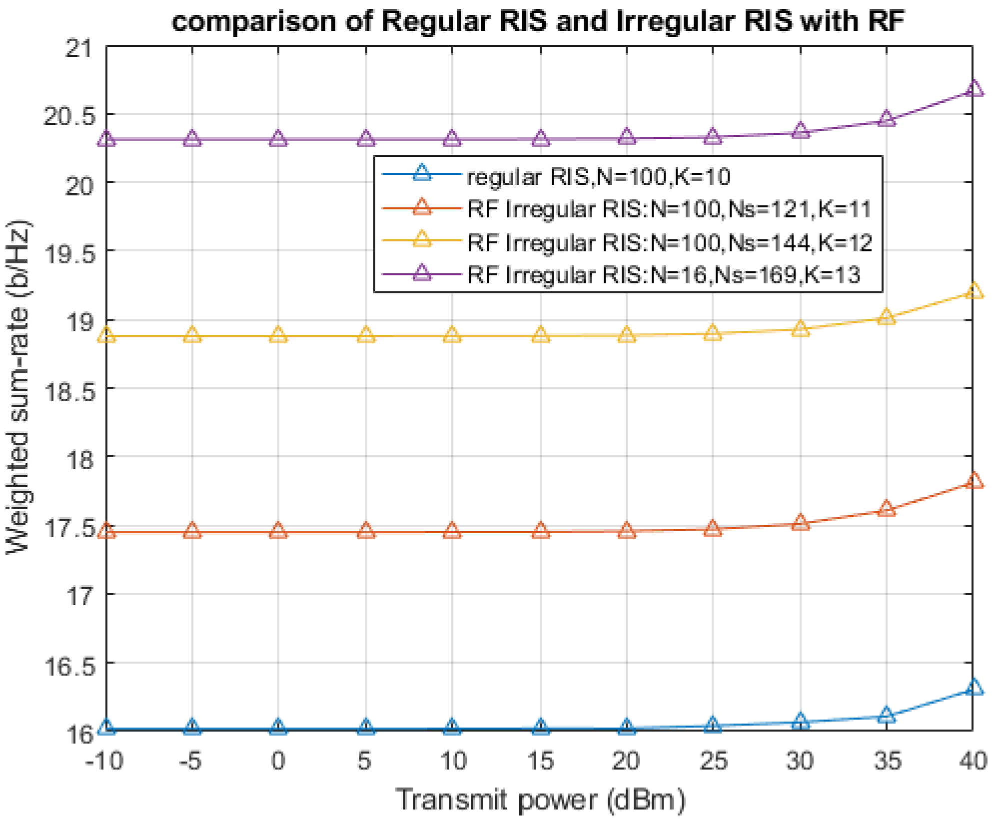

**Figure 9.** Comparison of WSR and the number of RIS elements. Transmit Power = 10 dBm, K = 4, Ns = 120

**Table 1.** the Computational Complexity Comparison

| | **Exhaustive based search** | **Modified Tabu Search[1]** | **Reinforcement Learning** |
|---|---|---|---|
| Ns=16 , N=8 | 3294720 | 1872000 | 1461200 |
| Ns=64,N=32 | $7.8711 * 10^{27}$ | 2088000 | 1759000 |

In Table 1, the complexity computations of different methods presented. According to the results RF has lower computation complexity with better Sum Rate Maximization.

According to figure 6,7,8,9 the Irregular RIS that optimized with Reinforcement Learning, has better Sum rate Maximization.

## Conclusion

The capacity of conventional wireless communication systems assisted by reconfigurable intelligent surfaces (RIS) is limited by their components. To address this challenge, the design of irregular reconfigurable intelligent surfaces is investigated in this study. Initially, an irregular RIS structure with a certain number of elements distributed over a large surface is proposed. Then, for the proposed irregular communication system assisted by RIS, a Sum Rate maximization problem is formulated to optimize the system capacity. Finally, a low-complexity joint optimization algorithm is proposed to iteratively solve the optimization problem. According to the results, the RF has better accuracy than

Tabou search Optimization algorithm. We suggest to merge evolutionary and RF algorithm to increase the Optimization convergence speed and Sum Rate Maximization.

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