International Journal of Interdisciplinary Telecommunications and Networking
Volume 18 • Issue 1 • January-December 2026

Dynamic Channel Optimization of Reconfigurable Intelligent Surface in Communications

Yanhong Zhang
http://orcid.org/0009-0001-8271-7595
Luzhou Vocational & Technical College, China
Received: August 1st, 2025 | **Accepted:** April 28th, 2026

ABSTRACT

Reconfigurable Intelligent Surface (RIS) is emerging as a key enabler for post-5G and beyond networks. To address performance degradation in dynamic channels, this paper proposes a prediction-decision-control closed-loop framework combining deep reinforcement learning and group decomposition for real-time RIS phase adjustment. Validated via simulations and a millimeter-wave prototype, the method outperforms greedy and convex optimization approaches in spectral efficiency, retains notable capacity gains in non-line-of-sight (NLoS) scenarios, cuts down control latency effectively, and boosts energy efficiency significantly compared with static and semi-static strategies. The study also explores physical layer security and green communications, offering insights into future RIS material design. These results advance the development of efficient, robust, and scalable intelligent wireless networks.

KEYWORDS

Reconfigurable Intelligent Surface (RIS), Communication, Dynamic Channel, Optimization, Wireless Network

INTRODUCTION

The evolution of 5G and future 6G networks toward ultra-dense deployment, millimeter-wave/TeraHertz bands, and ultra-low latency poses significant challenges for traditional cellular architectures. Traditional methods that rely on boosting transmit power or adding more antennas are now hitting physical and energy-efficiency limits (Alhammadi et al., 2024). Moreover, at high frequencies like the mmWave, signals suffer from strong attenuation and scattering, which degrades coverage and link reliability (Zhimwang et al., 2025). To meet this challenge, the academic community has proposed a variety of new physical layer technologies, one of which is the reconfigurable intelligent surface (RIS)—also known as the intelligent reflecting surface; it is a low-cost, low-power passive beamforming solution that has received widespread attention in recent years as a low-cost, low-power passive beamforming solution (Almekhlafi et al., 2023).

An RIS is composed of many programmable reflective elements. Each element can independently adjust the amplitude, phase, or polarization of incoming signals under external control, enabling the dynamic reshaping of the wireless environment without active radio frequency components (Liu et al., 2021). Compared with traditional active relay or large-scale multiple-input multiple-output systems, RIS does not require power amplifiers and complex signal processing modules, significantly

DOI: 10.4018/IJITN.409338

reducing hardware costs and energy consumption, and it has the advantages of flexible deployment and strong concealment (Basar et al., 2019). For this reason, RIS is regarded as one of the key enabling technologies for realizing green communications, intelligent reflection environments, and semantic communication infrastructure (Shi et al., 2022). Recent works have further explored purpose-oriented RIS designs for performance enhancement in vehicular and visible light communication scenarios (Wheeb et al., 2025; Wheeb et al., 2024). This aligns with the broader trend of integrating RIS into next-generation heterogeneous networks.

However, the high-speed mobility of end users, dynamic occlusion effects, and rapid time-varying multipath channels in real scenarios makes it difficult for static or offline optimized RIS reflection coefficients to maintain an optimal performance for a long time (Ibrahim et al., 2023). Especially in the millimeter wave frequency band, the narrow beam characteristics are highly sensitive to the accuracy of channel state information (CSI), and the traditional closed-loop control mechanism based on periodic channel estimation and feedback faces significant delay and overhead problems (Mei et al., 2024; X. Zhu et al., 2025). Therefore, relying solely on low-frequency reconfiguration or greedy search algorithms is ineffective for meeting the multiple quality of service requirements of immersive applications (such as extended reality, holographic communication, and telemedicine) for large capacity, high reliability, and low latency (Chen et al., 2024).

In order to solve the above problems, researchers began to explore the introduction of artificial intelligence (AI), especially deep reinforcement learning (DRL), into the RIS control system to achieve end-to-end adaptive optimization without accurate channel modeling (Jiang et al., 2022). DRL can learn complex nonlinear mapping relations from historical observation data through the continuous interaction between agents and the environment, which is suitable for high-dimensional, non-convex, and dynamic wireless resource management tasks (Hao et al., 2024). For example, the depth Q-network can be used for discrete phase selection, while the actor-critic architecture supports reflection matrix optimization in continuous motion space (Gholizadeh et al., 2023). However, the direct application of the standard DRL model still faces the problems of slow training convergence, low sample efficiency, and poor generalization ability, especially in multi-user and multi-RIS cooperation scenarios (Wang et al., 2022).

Despite the potential of DRL for RIS control, existing approaches still suffer from slow convergence, high computational complexity, and poor scalability in dynamic environments, which limits their real-time deployment. This work addresses a critical gap: how to achieve real-time, scalable, and low-complexity RIS control under fast time-varying channels without sacrificing performance. While DRL offers promise for adaptive optimization, existing methods treat the entire RIS as a monolithic entity, leading to high-dimensional action spaces that cause slow convergence and poor generalization—especially in large-scale deployments.

To overcome this, we first construct an end-to-end communication system based on a three-dimensional geometric channel model, comprising base stations (BS), RIS arrays, and mobile users and derive the quantitative relationship between reflection coefficients and system capacity and energy efficiency from an information-theoretic perspective (Y. Sun et al., 2017). A DRL architecture incorporating state clustering and action space decomposition is then designed to predict future channel trends from historical CSI sequences and enable rapid phase matrix decision-making. Finally, the framework is experimentally validated using a self-developed millimeter-wave RIS prototype platform, where system performance is assessed under various RIS scales, user mobility speeds, and scheduling strategies. Experimental results show that the proposed method significantly improves link stability and spectral efficiency under extremely low hardware overhead. Furthermore, practical challenges such as hardware non-ideal factors (e.g., quantization error, phase noise), algorithm convergence, and multi-RIS collaborative optimization are investigated, providing theoretical support and engineering insights for the design of future intelligent wireless networks.

12 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage: www.igi-global.com/article/dynamic-channel-optimization-of-reconfigurable-intelligent-surface-in-communications/409338

Related Content

Host Identity Protocol: The Enabler of Advanced Mobility Management Schemes
László Bokor, Szabolcs Nováczkiand Sándor Imre (2011). *Advanced Communication Protocol Technologies: Solutions, Methods, and Applications (pp. 247-272).*
www.irma-international.org/chapter/host-identity-protocol/54619

A Semantic Approach to Designing Information Services for Smart Museums
Dmitry G. Korzun, Sergey A. Marchenkov, Andrey S. Vdovenkoand Oksana B. Petrina (2016). *International Journal of Embedded and Real-Time Communication Systems (pp. 15-34).*
www.irma-international.org/article/a-semantic-approach-to-designing-information-services-for-smart-museums/180292

Adaptive Hierarchical Scheduling Framework for TiRTOS
Hesham Hussien, Eman Shaabanand Said Ghoniemy (2019). *International Journal of Embedded and Real-Time Communication Systems (pp. 119-135).*
www.irma-international.org/article/adaptive-hierarchical-scheduling-framework-for-tirtos/217004

Cross-Layer Protocols for Multimedia Communications over Wireless Networks
Jaydip Sen (2011). *Advanced Communication Protocol Technologies: Solutions, Methods, and Applications (pp. 318-354).*
www.irma-international.org/chapter/cross-layer-protocols-multimedia-communications/54622

Socio-Emotional Competencies and Well-Being in Online Educational Settings
Rocío Luque-González, Inmaculada Marín-Lópezand Mercedes Gómez-López (2024). *Encouraging Transnational Learning Through Virtual Exchange in Global Teacher Education (pp. 23-44).*
www.irma-international.org/chapter/socio-emotional-competencies-and-well-being-in-online-educational-settings/346836