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Advance Higher Throughput Communications and Networks for GEO and LEO satellites (3)

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# ENHANCING DOWNLINK EFFICIENCY FOR 6G USING RIS-ASSISTED BEAMFORMING IN LEO SATELLITE NETWORKS

**Abstract**

The rapid expansion of 6G networks has intensified the need for efficient satellite-to-ground communication, particularly in Low Earth Orbit (LEO) satellite networks, where signal degradation due to atmospheric interference and multipath fading remains a critical challenge. Traditional beamforming techniques struggle to maintain optimal downlink performance in dynamic environments. To address this issue, this research investigates the integration of Reconfigurable Intelligent Surfaces (RIS) to enhance signal strength, coverage, and power efficiency. We propose a novel RIS-assisted beamforming approach that leverages deep reinforcement learning (DRL) to dynamically optimize signal reflection patterns. The RIS, composed of programmable meta-surfaces, adjusts phase shifts to steer the reflected beam towards the user, improving signal quality. A Proximal Policy Optimization (PPO)-based DRL model is trained to maximize signal-to-noise ratio (SNR) and minimize power loss by continuously adapting RIS configurations based on real-time satellite positioning and channel conditions. Performance evaluations compared the proposed RIS-assisted system against conventional beamforming models, considering key metrics such as SNR, beam coverage, and power efficiency under various atmospheric and channel conditions. Results demonstrated that adaptive RIS configurations significantly improved downlink performance, especially in environments with signal blockages or severe multipath interference. However, this approach has limitations, including increased computational complexity due to real-time DRL optimization and potential hardware constraints in implementing RIS on LEO satellites. Future research will explore more energy-efficient learning strategies, practical RIS deployment architectures, and the integration of multi-agent learning for enhanced adaptability in large-scale satellite networks.