Leveraging Reconfigurable Intelligent Surfaces for Sustainable 6G Wireless Networks

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The imperative examination of the energy efficiency of 5th Generation (5G) networks demands the development of sustainable wireless communication technologies [1, 2]. The distributed nature of the 5G network architecture, with the deployment of numerous small cells—especially in densely populated urban settings—alongside complex technologies like beamforming and massive multiple-input and multiple-output (MIMO) antennas, integral to 5G, significantly contributes to the power consumption, resulting in increased operational costs and environmental concerns [3]. Furthermore, the upsurge in data traffic due to data-intensive applications (e.g., virtual reality, holographic and semantic communication) and a growing number of connected devices also play a substantial role in heightened energy demands within 5G networks. Addressing these inadequacies is crucial for laying the groundwork for 6th Generation (6G) networks. The strategic emphasis lies in accommodating diverse applications, ensuring faster and more reliable data transmissions, meeting stringent quality-of-service requirements, enhancing energy efficiency, and ensuring overall sustainability in our ever-connected world [4].

In meeting the rigorous criteria of 6G networks, a notable transformation emerges with the introduction of Programmable Wireless and Smart Radio Environments (SRE) [5, 6]. SRE allow dynamic control and adaptation of wireless communications through a software-defined process. They use electromagnetic metasurfaces to program and adjust various parameters such as signal strength, polarization and directionality, facilitating a more adaptive and efficient wireless network [7]. By enabling programmability, SRE open avenues for customization and integration of intelligence right at the physical layer, ensuring that wireless communication can be tailored to the specific applications, scenarios and user requirements. The integration of SRE marks a significant step forward in the evolution of 6G networks, promising enhanced performance, energy efficiency and sustainability.

Reconfigurable Intelligent Surfaces (RIS), also referred as Intelligent Reflecting Surfaces (IRS) have attracted considerable attention, as they are a crucial component within the broader concept of SRE, contributing to the programmable and intelligent management of wireless environments to optimize overall communication quality. RIS is composed of a planar surface equipped with multiple passive reflecting elements. These individual elements operate independently and possess the impressive capability to passively manipulate the polarization, direction, phase and power of an incoming electromagnetic signal while reflecting it [8]. This autonomous control mechanism serves to mitigate the effects of complex wireless propagation conditions, providing a more adaptive and efficient communication environment. Additionally, the introduction of an extra channel enhances the overall wireless connectivity, further optimizing the performance of the communication environment [9]. These attributes of RIS, coupled with the passively achieved programmable features, position it as a fundamental component in the development of sustainable 6G networks. Recognizing the significance of RIS, 6G SNS has now considered it a promising and integral part of 6G networks [10]. This acknowledgment strengthens the argument for the pivotal role that RIS in shaping the landscape of 6G networks, with a primary focus on energy efficiency and sustainability. The comprehensive nature of our research includes the design, development, and seamless integration of RIS into the fabric of 6G networks. This integration is aimed to foster an adaptive, energy efficient, and sustainable wireless communication infrastructure for 6G networks.

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