Refracting RIS-Aided Hybrid Satellite-Terrestrial Relay Networks: Joint Beamforming Design and Optimization

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Abstract:

Reconfigurable intelligent surface (RIS) has been viewed as a promising solution in constructing reconfigurable radio environment of the propagation channel and boosting the received signal power by smartly coordinating the passive elements' phase shifts at the RIS. Inspired by this emerging technique, this article focuses on joint beamforming design and optimization for RIS-aided hybrid satellite-terrestrial relay networks, where the links from the satellite and base station (BS) to multiple users are blocked. Specifically, a refracting RIS cooperates with a BS, where the latter operates as a half-duplex decode-and-forward relay, in order to strengthen the desired satellite signals at the blocked users. Considering the limited onboard power resource, the design objective is to minimize the total transmit power of both the satellite and BS while guaranteeing the rate requirements of users. Since the optimized beamforming weight vectors at the satellite and BS, and phase shifters at the RIS are coupled, leading to a mathematically intractable optimization problem, we propose an alternating optimization scheme by utilizing singular value decomposition and uplink–downlink duality to optimize beamforming weight vectors, and using Taylor expansion and penalty function methods to optimize phase shifters iteratively. Finally, simulation results are provided to verify the superiority of the proposed scheme compared to the benchmark schemes.

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Contents

As an emerging candidate for beyond 5G (B5G) and future 6G communication systems, satellite communications (SATCOM) have attracted significant attention in both military and civil applications owing to their advantages of vast communication coverage and long distance transmission, which can be widely utilized in disaster relief, global navigation, and communication access in unpopulated regions [1]–[5]. However, the quality-of-service (QoS) of SATCOM is vulnerably affected by shadow effects, and the line-of-sight (LoS) channel link would be severely deteriorated, especially in urban environments [6]. To address this issue, by employing terrestrial nodes as relays to forward and strengthen the satellite signals at the receivers, the architecture of hybrid satellite-terrestrial relay network (HSTRN) has been proposed in this regard for providing truly seamless connectivity in both densely and sparsely populated areas [7]–[9]. Recently,

significant efforts have been devoted to exploiting HSTRN from various perspectives. Specifically, Huang et al. [10] first obtained the beamforming vectors at the relay, and then the closed-form expressions for the outage probability and ergodic capacity with two scheduling schemes were derived in the considered HSTRN. In [11], two adaptive transmission schemes in HSTRN with decode-and-forward (DF) relaying protocol were investigated. Besides, Sharma et al. [12] focused on a hybrid satellite-terrestrial spectrum-sharing system, and investigated an overlay spectrum sharing protocol by proposing partial and opportunistic selection schemes. Moreover, a channel estimation and detection scheme was investigated by Arti [13], and then further derived the analytical diversity order of the HSTRN with channel gains estimation.

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