Deep Learning Based Beamforming and Metasurface Design for Reconfigurable Intelligent Surface

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Abstract

Reconfigurable intelligent surface (RIS) is a promising technology developed for improving signal coverage and capacity for the fifth and sixth generation (5G/6G) wireless systems. However, existing RISs have the following limitations. For deep learning (DL) based beamforming schemes, the effect of imperfect channel state information (CSI), imbalanced computing resources of federated learning (FL), relay-based single-task training of split learning (SL), and high labeling costs are still bottlenecks. For metasurface design, it concerns its narrow reflection phase range and bandwidth, insufficient reflection direction range, and unchangeable reflector shape.

In this dissertation, we first propose a centralized machine learning (CML) approach with leaky integrated-and-fire (LIF) mechanism to significantly eliminate the unexpected noise effects. Then, we extend this CML approach into the collaborative learning framework, named self-enhanced multi-task and split federated learning (SM-SFL) for RIS-aided cell-free (CF) systems. Simulation results show that this proposed approach can achieve a high spectral efficiency (SE) under the low signal-to-noise ratio (SNR) with multi-device cooperation and negligible labeling overhead.

Next, we propose the interdigital and multi-via structures to obtain a wide reflection phase range. Then, we also propose a varactor diode mounted structure to adaptively control the reflection direction and operating frequency band. In addition, we propose a convex-type multi-beam RIS to obtain a wide reflection direction range. A conformal RIS (CRIS) with a flexible printed circuit (FPC) substrate is also proposed to control the reflection direction and reflector shape. Measurement and simulation results show that the proposed RISs can control the reflected beam in the desired direction with high efficiency and flexibility.