Quantization and Attention-based Hierarchical DL Models for Beam Training in mmWave Massive MIMO Systems

Name: Haohui Jia (Stdnt.No: 2021422)
Laboratory's name: Network systems
Supervisor's name: Minoru Okada

Abstract (should be within 1st page)

Deep learning (DL) based beam training is the critical leverage in fifth/sixth generation (5G/6G) systems to preserve spectral efficiency with fast optimal beam selection. However, a unified DL structure hardly expresses the multiple subsets of rays/clusters for the millimeter wave (mmWave) massive multiple-input multiple-output (MIMO) systems. Moreover, a complex environment also incurs critical performance degradation for the continuous output. In practice, the high labeling and expertise cost is also inefficient and infeasible.

This study focuses on highly efficient, robust, and flexible beam training with intelligent proposals. We first explore a hierarchical paradigm based on frequency and spatial domain views. And then, we extend it to a novel contrastive learning framework working on a tiny fraction of the labeled CSI dataset. Specifically, we organize non-deterministic and autoregressive encoders for extracting the frequency information with the corrupt CSI. The proposed non-deterministic encoder turns the channel intensities into a binary representation, and the autoregressive encoder handles the interrelation of frequency and spatial domain. Benefiting from the transformer model, we apply a spatial attention encoder contributing to the optimal beam by scoring the relation between latent beam directions and generated beam gains. Leveraging the hierarchical paradigm, we further design a novel contrastive learning framework. We quantize the environmental components with a latent beam codebook to achieve robust representation. The proposed framework pre-trains by the contrastive information of the target user and others with the unlabeled CSI and then utilizes it as the initialization to fine-tune with negligible labeling cost.

Finally, experimental results show that this study outperforms existing DL-based schemes, obtaining higher capacity and highly reliable performance for mmWave massive MIMO systems. The proposed framework further enhances flexibility and breaks the limitation of the quantity of label information for practical beam training.

Keywords: 5G/6G, mmWave, massive MIMO, DL, non-deterministic, quantization, transformer, spatial attention, contrastive learning.