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Federated Learning for Channel Estimation in Intelligent Reflecting Surfaces With Fewer Pilot Signals

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1 Introduction

Channel estimation is a critical task in intelligent reflecting surface (IRS)-assisted wireless systems due to the uncertainties imposed by environment dynamics and rapid changes in the IRS configuration. To deal with these uncertainties, deep learning (DL) approaches have been proposed. Previous works consider centralized learning (CL) approach for model training, which entails the collection of the whole training dataset from the users at the base station (BS), hence introducing huge transmission overhead for data collection. To address this challenge, this paper proposes a federated learning (FL) framework to jointly estimate both direct and cascaded channels in IRS-assisted wireless systems. We design a single convolutional neural network (CNN) trained on the local datasets of the users without sending them to the BS. We show that the proposed FL-based channel estimation approach exhibits approximately 12 times lower transmission overhead than CL, while maintaining satisfactory performance close to CL. In addition, it provides lower estimation error than the state-of-the-art DL-based schemes.

Fig. 1a shows the channel estimation NMSE with respect to SNR. Notice that CL provides better performance than that of FL for the proposed CNN model since it has access to the whole dataset at once. Nevertheless, FL has satisfactory channel estimation performance despite decentralized training and outperforms SF-CNN with CL [1]. Specifically, the proposed CNN with FL and CL have similar NMSE for SNR$\leq$ 25 dB and the performance of FL maxes out in high SNR regime. This is because the learning model loses precision due to FL training and cannot perform better. SF-CNN also exhibits similar behavior but performs worse than the proposed method. This is because SF-CNN has convolutional-only layers. In contrast, the proposed CNN includes both convolutional and fully connected layers, exhibiting better feature extraction and data mapping performance [2].

Fig 1b shows the channel estimation NMSE with respect to the number of pilot signals $\bar{M}$ for SNR$=$ 20 dB. We can see that the proposed approach provides significantly better performance in the presence of insufficient pilot signals, i.e., $\bar{M} < M$, whereas the other algorithms perform poorly since they rely on the complete channel data, demanding $\bar{M} \geq M$.

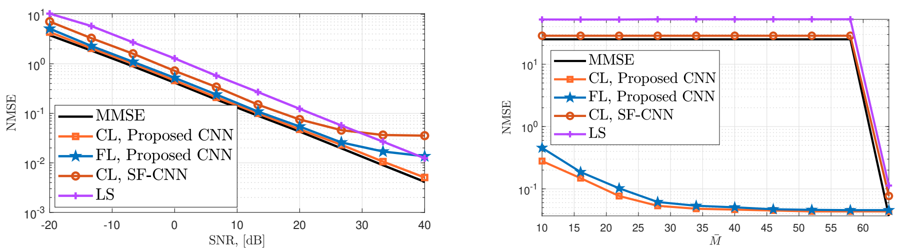

Figure 1. Channel estimation NMSE with respect to SNR when $\bar{M} = 32$ and $\bar{M}$ when SNR $= 20$ dB.

References

[1] A. M. Elbir and S. Coleri, "Federated Learning for Channel Estimation in Conventional and RIS-Assisted Massive MIMO," *IEEE Trans. Wireless Commun.*, p. 1, Nov 2021.

[2] A. M. Elbir and K. V. Mishra, "A Survey of Deep Learning Architectures for Intelligent Reflecting Surfaces," *arXiv preprint arXiv:2009.02540*, 2020.