A Learning-based Channel Estimation Method for Grant-Free Access in Massive MIMO Systems

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Massive MIMO 환경에서의 Grant-Free Access 를 위한 학습기반 채널 추정 기법 연구

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Abstract

Grant-free communication has attracted research interests as a promising technology for reducing uplink transmission delay. Channel estimation in massive multiple-input and multiple-output (MIMO) system is an essential and fundamental function in wireless communication systems, in which commonly used methods leverage orthogonal pilot signals for each channel medium they want to estimate. However, the orthogonality in pilot signals coerces all the devices synchronized and is inadequate for grant-free access. To overcome this issue, we propose a learning-based channel estimation method in massive MIMO systems with non-orthogonal cyclic redundancy check. Numerical results show that the proposed scheme achieves less than 10^{-3} bit error rate (BER) in scenarios where the numbers of received antennas are 32, 64, and 128 with the pilot overhead of 8 %.

Ⅰ. Introduction

In a massive multiple-input and multiple-output (MIMO) scenario, the conventional pilot-based channel estimation methods have limitations due to the orthogonality between pilots. To guarantee orthogonality, pilot signals of all devices should be synchronized, and such pilot synchronization makes grant-free access impossible. Specifically, if a new device accesses a base station (BS) already communicating with other ongoing devices, it is difficult for a pilot signal of the new device to be synchronized with the ongoing devices.

In addition, it is hard to get channel information in a limited pilot overhead massive MIMO scenario. If the number of devices is larger than the length of pilot signals, the orthogonality of pilot signals is broken, and channel estimation becomes hard [2]. To overcome the limitations caused by the pilot overhead and broken orthogonality, we propose a learning-based channel estimation method in massive MIMO systems with non-orthogonal cyclic redundancy check (CRC).

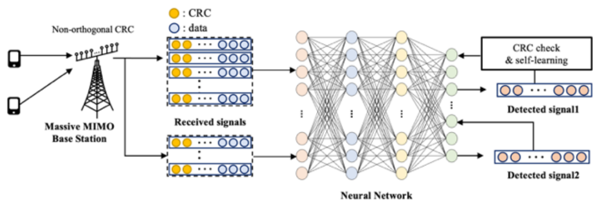

Fig. 1. Structure of the channel estimation in massive MIMO system.

Ⅱ. Method

In this paper, we propose a non-orthogonal CRC-based channel estimation method. Because each of CRCs does not have to be orthogonal, the devices are not forced to be synchronized. The proposed model is a kind of semi-supervised learning that only uses CRC information for learning. In other words, this model does not use transmitted data for learning and additional learning can be done while communication is going on.

Fig. 1 is a rough sketch of the entire communication system. We suppose a scenario that two devices communicate with a multi-antenna BS. A CRC is placed in front of the transmitted data. If we put received signals of each antenna and the corresponding CRC into proposed neural network, we can get channel information and detect the original data with this information.

Fig. 2 is a structure of the proposed model. The proposed model consists of a fully connected network with four hidden layers. The signals are complex values, whereas the weights of the neural network are real values [3]. Therefore, it is not appropriate to use raw data as input. Every single data needs to be separated into real and complex parts. Instead of the entire received signals, we use real and complex part of received signals of each antenna and the corresponding CRC as input data. If we use entire received signals as input data, the size of which increases in proportion to the number of received antennas.

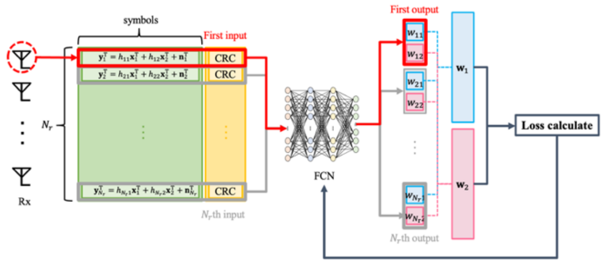

Fig. 2. Structure of the proposed model.

Let the number of received antennas be N_r. In massive MIMO systems, N_r is quite large and it makes the input size large enough to cause overfitting. Each output data means the channel information of each antenna. After gathering N_r antennas channel information, we can obtain channel information vectors $\mathbf{w}_1$ and $\mathbf{w}_2$, where $\mathbf{w}_1$ and $\mathbf{w}_2$ are real and imaginary part of the channel information, respectively. We use mean square error (MSE) of CRC and estimated CRC as a loss function. The loss is updated after running N_r times. If loss approaches to zero, the phase of $\mathbf{w}_1$ and $\mathbf{w}_2$ are getting closer to phase of the channel vector in massive MIMO system. The loss formula is as follows.

Loss: $\mathrm{MSE}(\mathbf{w}_1^{\mathrm{H}}\mathbf{y}_{\mathrm{CRC}}, x_{1,\mathrm{CRC}}) + \mathrm{MSE}(\mathbf{w}_2^{\mathrm{H}}\mathbf{y}_{\mathrm{CRC}}, x_{2,\mathrm{CRC}})$,
where $\mathbf{y}_{\mathrm{CRC}} = \mathbf{h}_1 x_{1,\mathrm{CRC}} + \mathbf{h}_2 x_{2,\mathrm{CRC}} + \mathbf{n}$

We test the proposed model in an 8% pilot overhead. Specifically, we transmit 140 OFDM symbols with 11 symbols for CRC and 129 symbols for data. We use QPSK as modulation scheme. We note that our model can be used with any other fixed constellation. As illustrated in Fig. 3, we simulate this model by changing the number of received antennas and signal-to-noise rate (SNR). Above 0 dB SNR, bit error rate (BER) is less than 10^{-3} when the numbers of received antennas are 32, 64, and 128.

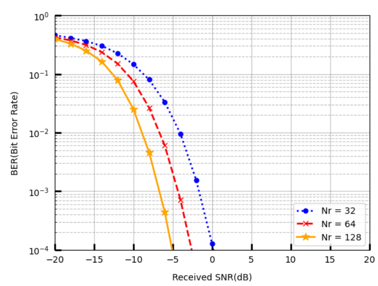

Fig. 3. BER for the number of received antennas.

Ⅲ. Conclusion

In this paper, we proposed a learning-based channel estimation method in massive MIMO systems with non-orthogonal cyclic redundancy check (CRC). The proposed model enables grant-free access using non-orthogonal sequences. We can also check feasibility of learning-based channel estimation. Since the proposed model is a semi-supervised learning, we can improve this model as an online learning model.

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REFERENCES

[1] K. Ito, T. Takahashi, S. Ibi and S. Sampei, "Bilinear Gaussian Belief Propagation for Large MIMO Channel and Data Estimation," *GLOBECOM 2020 - 2020 IEEE Global Communications Conference*, Taipei, Taiwan, 2020, pp. 1-6

[2] T. Kim and S. H. Chae, "A Channel Estimator via Non-Orthogonal Pilot Signals for Uplink Cellular IoT," in *IEEE Access*, vol. 7, pp. 53419-53428, 2019

[3] J. Gao, M. Hu, C. Zhong, G. Y. Li and Z. Zhang, "An Attention-Aided Deep Learning Framework for Massive MIMO Channel Estimation," in *IEEE Transactions on Wireless Communications*, vol. 21, no. 3, pp. 1823-1835, March 2022