Performance Evaluation of NN based MIMO Detection Method

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신경망 기반 MIMO 검출 방법의 성능 평가

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Abstract

In this paper, we propose a novel multiple input multiple output (MIMO) detection method by using a deep neural network (DNN) architecture. Our proposed DNN algorithm is leveraged with supervised training to solve the MIMO detection problem. We have developed a DNN network by considering the MIMO detection problem as a classification. We show that DNN with suitable choice of parameter and training can achieve better performance. Simulation results presented in this paper demonstrate that the proposed scheme achieves better error rate performance than conventional methods.

Ⅰ. Introduction

Multiple-input multiple-output (MIMO) system play a crucial role in achieving higher data rates [1]. As the demand for faster wireless services continues to rise, conventional single-input signal-output (SISO) systems equipped with a single antenna for both the transmitter and receiver may face limitations in meeting these demands for higher data services. In a MIMO system, several transmitting and receiving antennas are simultaneously used at the transmitter and the receiver end. However, this advantage leads to a trade-off with increased complexity at the receiver.

Traditional methods for MIMO detection cover a range of approaches, including both linear and non-linear methods. Linear techniques, like zero forcing (ZF) and minimum mean square error (MMSE) equalizers are widely used due to their low computational complexity [1]. However, their performance may be limited compared to non-linear detectors such as sphere decoding (SD). The computational complexity of SD method is higher which is not suitable for MIMO systems. Furthermore, the maximum likelihood (ML) is the optimal choice whose computational complexity makes it impractical [2].

Recent developments in deep learning (DL) have shown great success in MIMO detection. MIMO Detectors based on deep learning have also been developed and successfully applied to solve the MIMO detection problem. This opportunity allows us to reevaluate the design problem of MIMO receivers and explore the balance between complexity and performance trade-off [3].

II. Proposed DNN based MIMO detection

We consider a MIMO communication system, comprising NT transmit and NT receiving antennas. The received signal can be represented in complex domain as:

$$\mathbf{y} = \mathbf{H}\mathbf{s} + \mathbf{n}. \tag{1}$$

It is difficult to solve the complex-valued MIMO channel model directly. The following equation represents the conversion from complex-valued model to a real-domain:

$$\bar{\mathbf{y}} = \begin{bmatrix} \mathrm{Re}(\mathbf{y}) \\ \mathrm{Im}(\mathbf{y}) \end{bmatrix},\ \bar{\mathbf{s}} = \begin{bmatrix} \mathrm{Re}(\mathbf{s}) \\ \mathrm{Im}(\mathbf{s}) \end{bmatrix},$$

$$\bar{\mathbf{n}} = \begin{bmatrix} \mathrm{Re}(\mathbf{n}) \\ \mathrm{Im}(\mathbf{n}) \end{bmatrix},\ \bar{\mathbf{H}} = \begin{bmatrix} \mathrm{Re}(\mathbf{H}) & -\mathrm{Im}(\mathbf{H}) \\ \mathrm{Im}(\mathbf{H}) & \mathrm{Re}(\mathbf{H}) \end{bmatrix}.$$

In this way, the MIMO channel model can be written as:

$$\bar{\mathbf{y}} = \bar{\mathbf{H}}\bar{\mathbf{s}} + \bar{\mathbf{n}}, \tag{2}$$

where $\bar{\mathbf{y}} \in \mathrm{R}^{2NR}$, $\bar{\mathbf{H}} \in \mathrm{R}^{2NR \times 2NT}$, $\bar{\mathbf{n}} \in \mathrm{R}^{2NR}$ and $\bar{\mathbf{s}} \in \mathrm{R}^{2NT}$. The elements of $\bar{\mathbf{s}}$ are selected from a real equivalent constellation set.

The proposed DNN-based MIMO detection method employs a fully connected neural network architecture. Training and testing data were generated using (2). The neural network takes input data consisting of $\bar{\mathbf{y}}$ and $\bar{\mathbf{H}}$, which are used to classify $\bar{\mathbf{s}}$ through the neural network. We perform a multi-class classification by converting transmitted symbols into labels. The model consists of five DNN layers with different numbers of hidden nodes.

The training and testing batches are created for each signal-to-noise ratio (SNR) value separately. The testing of model is performed for each SNR with specific trained weights of the model obtained through training of model at particular SNR. To ensure effective model training, we utilize the Adam optimizer with a learning rate of 0.0001. Furthermore, for computing the loss during training, we employ the multi-class classification cross-entropy function.

III. Simulation Results

In Fig. 1, we demonstrate the bit error rate (BER) performance for 4 × 4 MIMO system with QPSK modulation. The Proposed method outperforms the ZF and MMSE methods. Despite ML method has the lowest BER, it has higher computational complexity than the proposed detection method.

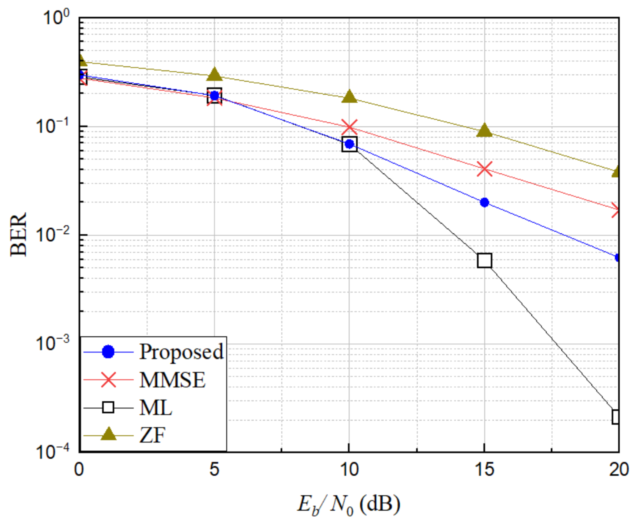

Fig. 1. BER performance comparison for a 4 × 4 MIMO system.

IV. Conclusion

In our paper, we proposed a DNN method for MIMO detection by employing multi-class classification approach. The proposed method has lower computational complexity than ML detection method. Our experimental results clearly showed that our method outperforms linear detectors.

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