Hybrid Attention – Quantum Based Mechanism for Hybrid Precoding Optimization

Adriansyah Dwi Rendragraha[1] and Soo Young Shin[2]
Department of IT Convergence Engineering, Kumoh National Institute of Technology
220116147@kumoh.ac.kr[1] and wdragon@kumoh.ac.kr[2]

Abstract

In this paper, hybrid attention – quantum based for hybrid precoding optimization is presented. The attention layer will be utilized to identify the features of user from channel matrix as input dataset, then used the features as input for quantum neural networks (QNN) for learning the optimize analog precoding that maximize the achievable spectral efficiency as the objective.

Keywords: Hybrid precoding, quantum neural network, wireless communication.

Ⅰ. Introduction

Hybrid precoding is proposed as promising solution to cover the limitation of digital and analog precoding, such as minimize the hardware cost and power consumption while maintaining near – optimal performance. Many studies has been utilize the hybrid precoding, in [1] zero-forcing is utilized to design hybrid precoding optimization. Reference [2], utilize attention mechanism with convolutional neural networks (CNN) to optimize the analog precoding, further used that to calculate digital precoding. Recently, several researchers [3],[4] explored the QNN based on wireless communication optimization problem to lower their complexity and achieving the similar result compared to classical NN.

This paper proposed hybrid attention – quantum for optimize the hybrid precoding. With the attention layer extracting the user features from dataset, the QNN will learning from features to generate optimize hybrid precoding.

Notation: $(\cdot)^H, (\cdot)^\tau$, and $(\cdot)^{-1}$ denotes as Hermitian, transpose, and inverse operation. Let $|\cdot|^2$ and $\|\cdot\|_f$ indicates determinant operation and frobenius norm.

Ⅱ. Method

Consider a mmWave MIMO system employ fully – connected hybrid precoding architecture on downlink scenario as illustrated in Fig. 1. Let the N_s, N_{RF}, N_T, and N_R indicate as number of data streams, radio frequency (RF) chain, transmitter antennas, and receiver antennas. The $\mathbf{P}_{\mathrm{BB}} \in \mathbb{C}^{N_{RF} \times N_s}$ and $\mathbf{P}_{\mathrm{RF}} \in \mathbb{C}^{N_{Tx} \times N_{RF}}$ denotes as digital and analog precoding, respectively.

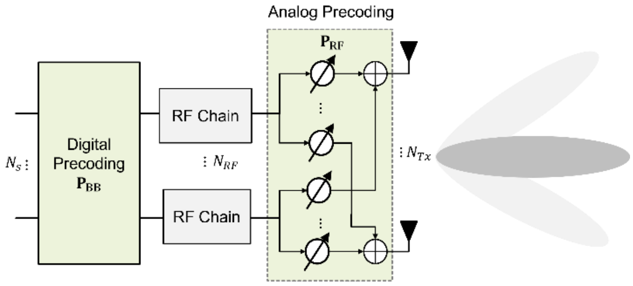

Fig. 1. System Model.

Saleh – Valenzuela channel employing a uniform linear array (ULA) antenna [5] is considered as the channel matrix corresponding to the k–th user, can be stated by:

$$\mathbf{h}_k = \sqrt{\frac{N_T N_R}{N_p}} \sum_{l=1}^{N_{path}} \boldsymbol{\omega}_l\, \mathbf{a}_T(\vartheta_k^T)^H \mathbf{a}_R(\vartheta_k^R), \quad (1)$$

where the following distributions are assumed $\boldsymbol{\omega}_l \sim \mathcal{CN}(0,1)$, $\vartheta^T \sim \mathcal{N}(0,2\pi)$, $\vartheta^R \sim \mathcal{N}(0,2\pi)$ to be the complex path gain with complex normal distribution, angle of departure (AoD), and arrival (AoA) with normal distribution. The N_p define as number of paths. Moreover, the steering vectors for both transmit and receive antennas are given as:

$$\mathbf{a}_T(\vartheta^T) = \frac{1}{\sqrt{N_T}}[1, e^{-j\pi\cos(\vartheta^T)}, \ldots, e^{-j\pi(N_T-1)\cos(\vartheta^T)}]^\tau, \quad (2)$$

$$\mathbf{a}_R(\vartheta^R) = \frac{1}{\sqrt{N_R}}[1, e^{-j\pi\cos(\vartheta^R)}, \ldots, e^{-j\pi d(N_R-1)\cos(\vartheta^R)}]^\tau. \quad (3)$$

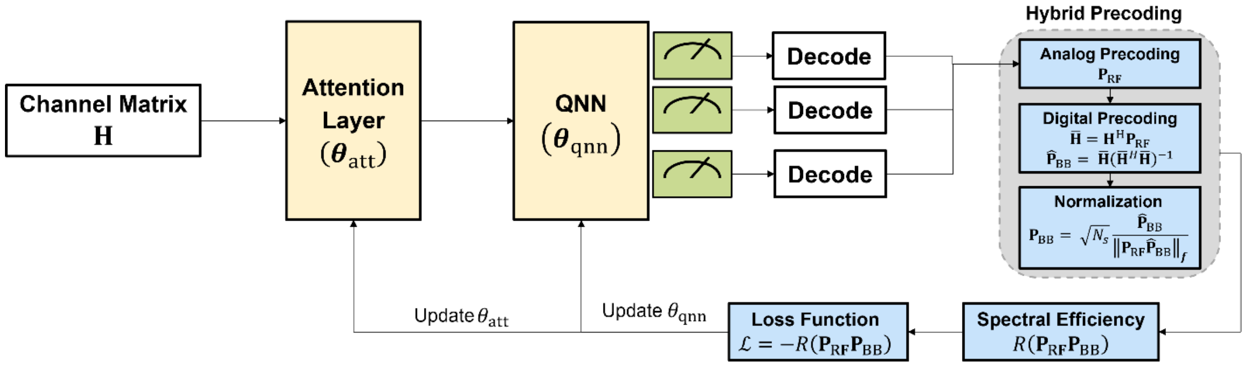

Fig. 2. Proposed Method.

As shown in Fig. 2, the channel matrix can be generated as dataset based on equation (1). Furthermore, attention layer will be utilize to process the channel matrix $\mathbf{H}$ and identify the inter-user interferences features. The extract features will be passed to QNN for learning the optimize analog precoding $\mathbf{P}_{\mathrm{RF}}$. Then, the digital precoding calculation can be obtained by using zero – forcing criteria by using channel effective $\bar{\mathbf{H}}$ [6] given as:

$$\bar{\mathbf{H}} = \mathbf{H}^H \mathbf{P}_{\mathrm{RF}}, \quad (4a)$$

$$\hat{\mathbf{P}}_{\mathbf{BB}} = \bar{\mathbf{H}}(\bar{\mathbf{H}}^H \bar{\mathbf{H}})^{-1}, \quad (4b)$$

$$\mathbf{P}_{\mathrm{BB}} = \sqrt{N_s}\frac{\hat{\mathbf{P}}_{\mathbf{BB}}}{\left\|\mathbf{P}_{\mathrm{RF}}\hat{\mathbf{P}}_{\mathbf{BB}}\right\|_f}. \quad (4c)$$

The signal–to–interference–plus–noise ratio (SINR) at k–th user can be define [] as:

$$\gamma_k = \frac{\rho\left|\boldsymbol{h}_k^{\tau}\mathbf{P}_{\mathrm{RF}}\boldsymbol{p}_{\mathrm{BB},k}\right|^2}{\sigma^2 + \rho\sum_{z\neq k}\left|\boldsymbol{h}_k^{\tau}\mathbf{P}_{\mathrm{RF}}\boldsymbol{p}_{\mathrm{BB},z}\right|^2}, \quad (5)$$

where ρ is signal–to–noise ratio (SNR). The objective of this paper to maximize the achievable rate as $R = \sum_{k=1}^{K} \log_2(1 + \gamma_k)$. The loss function of this hybrid precoding optimization can be expressed as $\mathcal{L} = -R$.

Ⅲ. Conclusion

This paper considered a mmWave MIMO hybrid precoding based on hybrid attention – quantum optimization. It shown that the proposed method is feasible for hybrid precoding optimization problem.

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