Deep Learning for Short Packet Transmissions over Flat Fading Channels

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***Abstract*—This paper investigates the performances of a deep-neural-networks scheme for decoding polar coded short packets that are transmitted over frequency-flat fading. Computer simulation results confirm that the proposed technique achieves the coding gain with learning epoch larger than 2^{12}.**

***Index Terms*—polar codes, packet combining, deep learning, short packet, lossy forwarding**

I. Introduction

Achieving ultra-reliable and low-latency communication is one of the major challenges facing future wireless communications, especially 5G technology. One way to minimize the latency is by using short packets. However, it causes a severe degradation in channel coding gain. On the other hand, ensuring reliability usually require more resources, e.g., redundancy, retransmissions, and hence increasing latency. Inspired by the recent success of machine learning approaches in wireless communications [1], we propose a deep neural network, also known as deep learning, scheme to design the neural network (NN) decoder for such short packet transmission without adding more resources to the packets.

II. System Model

We consider single carrier signaling, where binary streams $\mathbf{u} \in \mathbb{R}^k$ are encoded with polar codes as the channel encoder, generating codewords $\mathbf{d} \in \mathbb{R}^N$. The codewords are then mapped to binary phase shift keying (BPSK) symbols $\mathbf{x} \in \mathbb{R}^N$, and transmitted over the frequency-flat quasi-static Rayleigh fading channels with a complex channel coefficient h. The received signal $\mathbf{y} \in \mathbb{C}^N$ is a complex number given by $\mathbf{y} = h \cdot \mathbf{x} + \mathbf{n}$, where $\mathbf{n}$ is a noise component modeled by a complex Gaussian random variable with zero mean and variance $\sigma^2/2$ per dimension.

The receiver detects the signal as

$$\hat{\mathbf{x}} = \frac{h^*}{|h|^2} \cdot \mathbf{y}, \tag{1}$$

where $(\bullet)^*$ is the complex conjugate operator. By Gaussian distribution assumption of the received signal, we can obtain the log-likelihood ratio (LLR) values of each unit by

$$\text{LLR}(\hat{\mathbf{x}}) = \ln \frac{P(x=0|\hat{x})}{P(x=1|\hat{x})} = \frac{2}{\sigma^2} Re(\hat{x}), \tag{2}$$

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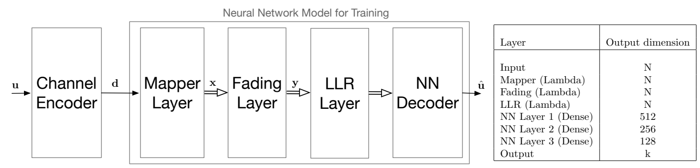

Fig. 1. Proposed deep learning scheme

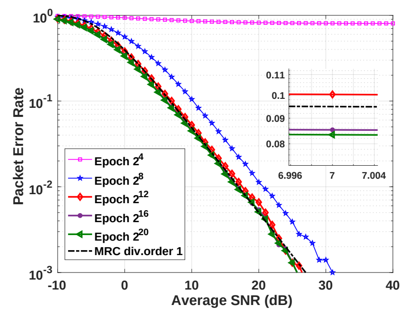

Fig. 2. PER performances

where $Re(\bullet)$ returns the real part of the complex number $(\bullet)$. Eventually, the trained NN decoder decodes the LLR values to obtain $\hat{\mathbf{u}}$. The NN decoder is trained by the proposed deep learning scheme as shown in Fig. 1.

III. Performance Evaluation

We use Keras as the front-end of Tensorflow platform to run the NN model, with configuration as given in Fig. 1. The model is trained at SNR -2 dB. Varies learning epochs return different packet error rate (PER) performances when testing the system with $k = 8$ and $N = 16$, as shown in Fig. 2. The coding gain can be achieved with learning epoch larger than 2^{12}.

IV. Conclusion

The proposed NN decoder for short packet transmissions over flat fading channels achieves coding gain with learning epoch larger than 2^{12}.

References

[1] Q. Zhang, P. P. Liang, Y. Huang, Y. Pei, and Y. Liang, "Label-assisted transmission for short packet communications: A machine learning approach," *IEEE Transactions on Vehicular Technology*, vol. 67, no. 9, pp. 8846–8859, Sept 2018.