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Review of Channel Prediction & Estimation based on Machine and Deep Learning Techniques

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***Abstract*— Channel prediction estimation in the high-speed mobile environment is a hot issue for 3D massive multiple input multiple output (MIMO) millimeter-wave (mmWave) system. In this environment, the channel has fast time-varying and non-stationary characteristics. And its time-domain correlation coefficient is a time-varying parameter, which makes it difficult for traditional channel estimation methods to capture the channel variations over time and achieve ideal channel estimation performance. Artificial intelligence based machine and deep learning techniques are capable to predict and estimate the wireless channel more efficiently. This paper review of the different channel estimation techniques based on ML & DL algorithms.**

***Keywords*— Channel, 5G, MIMO, mmWave, 3D, Deep, Machine.**

I. INTRODUCTION

Channel estimation is a technique used in communication systems to estimate the characteristics of a communication channel. In wireless communication, the signal transmitted from the transmitter undergoes different types of distortions such as fading, attenuation, and noise during its transmission through the wireless channel. Channel estimation is used to estimate the channel's characteristics so that the receiver can compensate for these distortions.

Channel estimation is performed by transmitting a known signal (called a pilot signal) from the transmitter, which is then received by the receiver. The receiver uses the received pilot signal to estimate the characteristics of the channel, such as the amplitude and phase of the signal.

Efficient utilisation of adaptive modulation and coding ensures the quality transmission of information bits through the significant reduction in bit error rate (BER). Channel prediction using parametric estimation is not efficient for massive machine-type communication (mMTC) devices under the 5G New Radio (NR) [1].

The investigation of the massive multi-input multi-output (MIMO) system in practical deployment scenarios, in which, to balance the economic and energy efficiency with the system performance, the number of radio frequency (RF) chains is smaller than the number of antennas. The base station employs antenna selection (AS) to fully harness the spatial multiplexing gain. Conventional AS techniques require full channel state information (CSI), which is time-consuming as the antennas cannot be simultaneously connected to the RF chains during the channel estimation process [2].

Channel estimation is an important part of modern communication systems, particularly in wireless communication systems, where the channel characteristics can change rapidly due to the movement of mobile devices or changes in the environment. Accurate channel estimation can improve the performance of the communication system, particularly in terms of data rate and reliability [3].

Channel prediction is the process of forecasting the future behavior of a communication channel based on its past behavior. This technique is commonly used in wireless communication systems to compensate for the effects of channel variations caused by changes in the environment or movement of mobile devices [4].

Channel prediction is performed by analyzing the past behavior of the channel and using statistical techniques to model the channel's behavior. This model can then be used to predict the channel's future behavior, which can be used to improve the performance of the communication system [5].

Channel prediction can be used to improve the performance of communication systems by providing advanced knowledge of the channel's behavior. This knowledge can be used to adjust the transmission parameters of the communication system, such as the modulation scheme and the transmit power, to optimize the performance of the system. Additionally, channel prediction can be used to improve the quality of real-time applications, such as voice and video, by reducing the impact of channel variations on the received signal [6].

Deep learning techniques, such as artificial neural networks, can also be used for channel prediction in communication systems. In this approach, the neural network is trained using historical channel data, and it learns to predict the channel behavior based on the input data [7].

The input data to the neural network can include various parameters that describe the channel's behavior, such as the channel gain, phase, and delay spread. The neural network learns to map these input parameters to the predicted channel behavior [8].

One advantage of using deep learning techniques for channel prediction is that they can learn complex patterns in the data that may be difficult to model using traditional statistical techniques [9]. Additionally, deep learning techniques can adapt to changing channel conditions more easily than traditional techniques, since the neural network can be retrained using new data as the channel conditions change [10].

II. LITERATURE SURVEY

V. Sharma et al.,[1] presented a channel prediction scheme based on a deep learning (DL) algorithm possessed by parametric analysis. In deep learning, the pipeline methodology is used along with the image processing technique to predict the channel condition for optimal selection of the adaptive modulation and coding (AMC) profile. The deep learning-based pipelining approach utilises image restoration (IR) and image super-resolution (SR). The super-resolution method is used to de-noise the low-pixel 2-D image that is obtained from the parametric value of the beacon to predict the channel condition.

M. Gaballa et al.,[2] In this work, the influence of Deep Neural Network (DNN) in predicting both the channel parameters and the power factors for users in a Power Domain Multi-Input Single-Output Non-Orthogonal Multiple Access (MISO-NOMA) system is inspected. In channel prediction based Deep Learning (DL) approach, we integrate the Long Short Term Memory (LSTM) learning network into NOMA system in order that LSTM can be utilized to predict the channel coefficients. In addition, in Deep Learning based power estimation method, we introduce an algorithm based on Convolutional Neural Network (CNN) to predict and allocate the power factor for each user in MISO-NOMA cell. DNN is trained online using channel statistics in order to approximate the channel coefficients and allocate the power factors for each user, so that these parameters can be utilized by the receiver to recover the desired data.

K. He et al.,[3] proposed JCPAS framework is a fully probabilistic model driven by deep unsupervised learning. The proposed framework is able to predict the current full CSI, while requiring only a historical window of partial observations. Extensive simulation results show that the proposed JCPAS can significantly improve the system performance under temporally correlated channels, especially for very large-scale systems with highly correlated channels.

Y. Shao et al.,[4] design a novel deep learning (DL) based channel prediction network that combines the benefits of fully-connected deep neural network (FC-DNN), convolutional neural network (CNN) and long short-term memory (LSTM) to reduce the demand of pilot symbols in orthogonal frequency-division multiplexing (OFDM) systems. In particular, the three networks are deployed to perform noise reduction, interpolation and prediction, respectively. In addition, we propose a data aided decision feedback scheme in prediction to guarantee the prediction performance. Simulation results demonstrate that the proposed prediction network can achieve better performance than existing methods.

S. W. Chu et al.,[5] The nature of the problem requires comprehensive global contextual reasoning among joints in different locations. In this work, we explore how to incorporate two popular and effective concepts, self-attention and Graph Neural Network (GNN), to model long-range information in HPE. Three different ways to implement self-attention in 3D feature maps are studied, where the best result is achieved via the channel-position version. Accuracy is further improved by refining the queries via an efficient channel-wise parallel GNN that explicitly models the human joint graphical relationships.

G. Liu et al.,[6] In massive multiple-input multiple-output orthogonal frequency division multiplexing (MIMO-OFDM) systems, a challenging problem is how to predict channel state information (CSI) (i.e., channel prediction) accurately in mobility scenarios. However, a practical obstacle is caused by CSI non-stationary and nonlinear dynamics in temporal domain. In this work, we propose a spatio-temporal neural network (STNN) to achieve better performance by carefully taking into account the spatio-temporal characteristics of CSI. Specifically, STNN uses its encoder and decoder modules to capture the spatial correlation and temporal dependence of CSI. Further, the differencing-attention module is designed to deal with the non-stationary and nonlinear temporal dynamics and realize adaptive feature refinement for more accurate multi-step prediction.

S. Bhattacharya et al.,[7] An efficient channel estimation is of vital importance to help THz communication systems achieve their full potential. Conventional uplink channel estimation methods, such as least square estimation, are practically inefficient for THz systems because of their large computation overhead. In this work, we propose an efficient convolutional neural network (CNN) based THz channel estimator that estimates the THz channel factors using uplink sub-6GHz channel.

T. Ngo et al.,[8] Channel profiles or power delay profiles (PDP), representing multipath fading propagation conditions, are used for linklevel performance evaluation and optimization. Channel state information (CSI), acquired via channel estimation techniques, lumps all multipath components and hence contains no delay profiles. This work presents a Deep Learning (DL) based methodology to categorically predict LTE and 5G channel.

W. Luo et al.,[9] In order to track the variations of time-varying mmWave channel and perform channel estimation, a deep learning-based channel estimation network is proposed in this work. In the design of the deep neural network, a CNN+RNN network structure is used to learn the characteristics of channel. Considering that the 3D mmWave channel has sparsity in both spatial and frequency domains, a convolutional neural network (CNN) is used to extract the spatial-frequency domain features of the channel response. Afterwards a maximum pooling network is used to reduce the training parameters of the network. Finally, a recurrent neural network (RNN) is used to extract the time-domain correlated features of the channel response to estimate the channel. In offline training phase, channel state information (CSI) at pilot is firstly initialized by least squared method, and an incomplete channel matrix with estimated values only at the pilot point is obtained. In order to estimate the values at the data points and complete the CSI matrix, the incomplete CSI is fed into the network and standard high-speed channel data is used to train the network. Simulation results show that the proposed method can track the variations of channel characteristics in a high-speed mobile environment and achieve better performance in the online prediction phase compared to conventional methods.

P. Bhattacharya et al.,[10] work highlights the importance of channel prediction during channel estimation (CE) in an energy efficient wireless communication system. Specifically, an energy beamforming-assisted multi-antenna system is considered in which energy receiver sends pilot signal to energy transmitter for CE. A long-short term memory based neural network is then utilized for predicting channel characteristics with respect to past CEs. Performance of learning strategy is evaluated, and efficacy of proposed approach is verified by varying number of estimations against predictions and observing maximum energy harvested at receiving antenna. Proposed scheme is also compared and found to outperform two existing benchmarks.

III. CHANNEL PREDICTION BY DEEP LEARNING

There are several deep learning techniques that can be used for channel prediction in communication systems, including:

1. Recurrent Neural Networks (RNNs): RNNs are a type of neural network that can maintain a memory of past inputs and use this information to predict future outputs. They are well-suited to time-series data, such as channel data, and can be trained using backpropagation through time.
2. Long Short-Term Memory (LSTM) networks: LSTMs are a type of RNN that are designed to avoid the vanishing gradient problem, which can occur when training traditional RNNs. LSTMs have been shown to be effective for channel prediction in wireless communication systems.
3. Convolutional Neural Networks (CNNs): CNNs are a type of neural network that are commonly used for image processing tasks, but can also be applied to time-series data. They can learn spatial features from the input data and can be used for channel prediction by treating the channel data as a 1D signal.
4. Autoencoder networks: Autoencoders are a type of neural network that can learn to compress the input data into a lower-dimensional representation and then reconstruct the original data from this representation. Autoencoders can be used for channel prediction by training the network to reconstruct the future channel data from the past data.

5. Generative Adversarial Networks (GANs): GANs are a type of neural network that can learn to generate new samples of data that are similar to the input data. They have been used for channel prediction by training the GAN to generate future channel data based on the past data.

IV. CONCLUSION

Channel prediction and estimation are critical techniques for improving the performance of communication systems in dynamic environments. Machine learning and deep learning techniques have been shown to be effective for channel prediction and estimation, offering the potential to learn complex patterns in the data and adapt to changing channel conditions more easily. In future take public available dataset and apply efficient deep learning techniques and optimized the improved performance for 5G communication applications.

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