Joint Optimization of Modulation and Guard Band Assignment with DNN-Based Channel Estimation in RoF Broadcasting System

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*Abstract*—We propose a nonlinear impairments-aware channel estimation model based on deep neural network (DNN) to conduct optimal dynamic modulation format and guard band assignment for RoF broadcasting system.

Keywords—channel estimation, RMSA, deep neural network, RoF.

# extended abstract

The next-generation multimedia transmission places higher requirements on the transmission distance and access capability of the network in order to carry emerging heterogeneous and bandwidth-intensive services, such as autonomous driving and telemedicine. Currently, the most widely used technology of transmission and broadcasting network is Radio-over Fiber (RoF) system, which combines the convenience in accessing from wireless broadcasting domain and the flexibility in resource allocation from the optical transmission domain. By modulating the radio broadcasting signals onto the spectrum in the orthogonal frequency division multiplexing (OFDM) format for transmission by elastic optical network (EON), RoF broadcasting system supports real-time adjustment of resource allocation schemes, namely Routing, Modulation and Spectrum Allocation (RMSA). For each transmission route, the spectral resource is divided into many orthogonal sub-carriers and allocated to different service requests in different modulation formats. Therefore, RMSA is often manifested as difficult online decision-making tasks, where appropriate allocation rules are important for the optimization of the next-generation multimedia RoF broadcasting system.

Channel estimation, as an important process in RMSA of RoF system, aims to grasp the channel state information (CSI) of each link, so as to make more targeted resource allocation. Some commonly used channel estimation algorithms have been studied extensively, however, few is fully capable for the requirements of the next-generation multimedia RoF broadcasting system. The accuracy of the least squares (LS) channel estimation proposed in [1] is greatly affected by the interference channel and noise of adjacent carriers, which is not suitable for the inevitable non-linear impairments in RoF system. [2] utilized a minimum mean square error (MMSE) channel estimation, which can suppress the interference of adjacent channels and noise to a certain extent. However, MMSE requires known second-order statistics, which is almost impossible to obtain in real time and involves a large number of matrix inversion operations. In [3], a Compressed sensing based channel estimation was proposed which effectively utilized the underlying structure of the channel state information. By using the dimensionality reduction idea, CS simplifies the large number of matrix calculations. Nevertheless, it relies heavily on the assumption on some sparse basis and the choice of mathematical methods. Therefore, a channel estimation method which can well perceive nonlinear impairments and has low computational complexity needs to be proposed to support the further optimization of RMSA.

Deep Neural Network (DNN) has the advantages of strong nonlinear fitting ability, simple matrix conversion, high real-time calculation efficiency, and the ability to improve the performance by self-evolution. In recent researches, DNN has shown a powerful ability in the treatment of complex nonlinear problems in many fields. In our previous work [4], we proposed a DNN-based channel estimation model to overcome the shortcomings of traditional methods in the weak perception of nonlinear impairments. Furthermore, in combination with the guard band scheme in OFDM-EON, we proposed a corresponding RMSA algorithm, namely DBRMSA, which uses the result of DNN channel estimation model to the guard band reallocation. Specifically, DBRMSA first extracts the mixed impairments of each link and judges the non-linear impairment extent through the DNN channel estimation model. Then DBRMSA reduces the guard band for the links effected more by linear impairment and, in the contrary, allocates additional guard band for the links effected more by nonlinear impairments, respectively. The experimental results show that under high load, DBRMSA has improved the utilization of spectral resources and also reduced the blocking rate of the whole network. The reasons can be summarized as follows. First, the compensation methods of linear impairments is rather mature, so less guard band can be tolerated. Second, according to the experimental observations, as the traffic being heavy, much more linear impairments-affected links will be involved than nonlinear impairments-affected links. As a result, the bandwidth saved is much more than those added. Finally, the DNN channel estimation model reduced the computation complexity, therefore improved the efficiency in computation process and reduced blocking rate.

However, the above research can be extended. For RoF broadcasting system, the modulation format of the broadcasting signals can be considered as the link between the broadcasting domain and the transmission domain during the photoelectric conversion process, which is an important entry point for optimization. Based on a proper allocation strategy of the guard band, dynamically adjusting the modulation format of the broadcasting signals according to the real-time channel status can help not only to further improve the robustness of the system to non-linear impairments, but also to reduce the bandwidth and improve spectrum resource utilization.

In this paper, we conduct our work in three parts. First, we further optimize DNN channel estimation model to achieve a quick convergence to the optimal result in larger network topologies. Second, we find the optimal mapping relationship between the channel state and the modulation format with the aim of promoting spectrum resource utilization. Third, an improved RMSA strategy based on the optimized DNN channel estimation model is proposed, namely RMGSA. RMGSA jointly and dynamically adjusts the guard band and modulation format according to the real-time CSI, and comprehensively considers the tradeoff between the carrying ability of the spectral resource and the channel capacity of the wireless broadcasting.

Through a joint mathematical modulation of the wireless broadcasting domain and the OFDM-EON transmission domain of the RoF broadcasting system, the problem of RMGSA can be mapped to a multi-objective optimized integer linear programming (ILP) problem. Convex optimization algorithms have been extensively studied in recent multi-objective optimization problems with the great advantages that its local optimal solution is equal to the global optimal solution, which can greatly reduce the delay and complexity in the calculation of optimal solution. Therefore, we reformulate the problem into a convex optimization problem through several assumptions and arguments.

The main contribution of our work can be summarized as follows:

1.We improve the performance of the nonlinear impairments aware DNN channel estimation model so that it can quickly converge to the optimal result and be more suitable for the large-scale next-generation multimedia RoF broadcasting system.

2.We jointly consider the modulation format in the wireless broadcasting domain and the guard band allocation in the optical transmission domain. Therefore, we can perceive the whole network status more accurately to make better global control and allocation schemes.

3.By analyzing the characteristic of RoF broadcasting system, we mathematically reformulated the RMSA algorithm into a convex problem. The convex optimization algorithm is introduced in our proposed RMSA algorithm, which reduces the computation delay and blocking rate.

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