Cover Letter

Graph Attention Reinforcement Learning for Age-Optimal Multicast Scheduling and Routing

Dear Editors and Reviewers:

Part of the results in this IEEE Journal on Selected Areas in Communications submission entitled "Age-minimal Multicast by Graph Attention Reinforcement Learning" is currently under review for IEEE GLOBECOM 2024, as attached. Compared with the conference paper, the key extension and major novelty of this journal submission are as follows.

1. **Learning the underlying combinatorial optimization of multicast routing.** In this JSAC submission, one of the major modifications we have made is providing a more systematic explanation and comprehensive analysis of the application of reinforcement learning (RL) for learning the heuristics of multicast routing. This enhanced explanation allows for a clearer understanding of the methodology and its implications in the context of multicast routing. Specifically, distinct from the GLOBECOM submission, we have introduced a transformation of the initial multicast optimization problem in **P2** into a more tractable equivalence in **P2-B**. We established and demonstrated the equivalence, and furthermore, we have made modifications to our quality function within the MDP framework. We can then successfully decompose the original problem into two subtasks that are well-suited for hierarchical RL methods.

2. **The perspective of cross-layer design.** In our GLOBECOM submission, we did not specifically analyze the relationship between the scheduler and the tree generator. However, in this current submission (Section IV), we introduce a cross-layer design that effectively combines both the scheduler and the tree generator. Notably, our numerical experiments demonstrated the cross-layer design's efficacy in achieving age-optimal multicast performance.

3. **Convergence analysis.** Another major extension of this JSAC submission is that we have further proved that the graph attention mechanism satisfies the contraction mapping, which guarantees its convergence at a linear rate. This JSAC submission has provided the proof of convergence of Algorithm 1.

4. **We extend our experiment results over additional environment settings, metrics, and baselines.** In this submission (Section VI), we conduct extensive experiments. Specifically, we add the network dynamics in the environment setting. We consider an additional AoI metric, i.e., the max weighted AoI to measure the fairness of different algorithms. We also add baselines including (i) An ablation of model architecture to validate the effectiveness of our proposed GAT; and (ii) A traditional MST generator to exhibit the performance compared to other approximation algorithms of multicast.

In addition, we have carefully extended and updated the introduction, literature review, and proofs. Overall, this journal submission is substantially different from the conference paper. We hope that you will enjoy reading this JSAC submission and look forward to your comments.

Sincerely yours,
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