Being more Effective and Interpretable: Bridging the Gap Between Heuristics and AI for ABR Algorithms

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ABSTRACT

In this poster, we propose several novel ABR approaches, namely BBA$^+$ and MPC$^+$, which are the fusion of heuristics and AI-based schemes. Results indicate that the proposed methods perform better than recent heuristic ABR methods. Meanwhile, such methods have also become more interpretable compared with AI-based schemes.

CCS CONCEPTS

• **Information systems** → *Multimedia streaming*; • **Computing methodologies** → *Neural networks*;

KEYWORDS

Adaptive Bitrate Streaming, Heuristics, Explainable-AI

ACM Reference Format:

Tianchi Huang, Rui-Xiao Zhang, Xin Yao, Chenglei Wu, Lifeng Sun. 2019. Being more Effective and Interpretable: Bridging the Gap Between Heuristics and AI for ABR Algorithms. In *SIGCOMM '19: ACM SIGCOMM 2019 Conference (SIGCOMM Posters and Demos '19), August 19–23, 2019, Beijing, China.* ACM, New York, NY, USA, Article 4, 3 pages. https://doi.org/10.1145/3342280.3342291

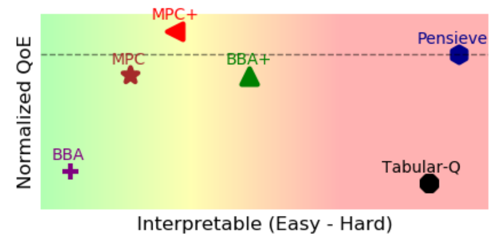


Figure 1: We consider proposing novel ABR approaches, which are the fusion of heuristics and AI-based schemes. As shown, BBA$^+$ and MPC$^+$ work better than heuristics and become more interpretable compared with AI-based schemes.

1 INTRODUCTION

Internet video streaming and downloads will grow to more than 82% of all consumer Internet traffic by 2022 [2]. Due to the fluctuation of network conditions and diversity of video contents, many adaptive bitrate (ABR) methods (e.g., *heuristics* and *AI-based*) have been proposed to provide video streaming services to the users with high quality of experience (QoE). However, heuristics like BBA [3] and MPC [8] can be easily interpreted but inevitably fail to achieve optimal performance. On the contrary, despite the outstanding improvements that AI-based schemes achieve, such ABR methods [5] are often modeled as a *black box*, which have lack of interpretability. Nevertheless, demystifying the working principle of AI-based methods is still non-trivial. E.g., it's formidable to correct the unexpected strategy if we barely understand how the method works. Thus, we ask if AI-based methods will assist heuristics to work better, and in the meanwhile, heuristics will also improve the interpretability of AI-based methods (See Figure 1). In other words, *is there any possibility of fusing heuristics and AI-based methods?*

In this poster, we attempt to adopt deep learning (DL) methods to enhance the performance of traditional heuristics and preserve the fundamental principle of each heuristics. In details, we consider two classical heuristic-based methods, i.e., BBA and MPC. After meticulously addressing the sub-goal for each model and distinguishing whether the module is represented by DL or heuristics, we propose two ABR DL+heuristic approaches, that involves:

- BBA$^+$: Utilizing Deep Neural Network (DNN) to estimate the suitable buffer-bound for controlling BBA algorithm.
- MPC$^+$: Leveraging DNN to predict future throughput and discounted factor, which guides the heuristic method to achieve better performances.

To this end, each module has a clear sub-goal that can be easily explained. We utilize linear reward QoE_{lin} with default parameter settings to evaluate our proposed methods. Using trace-driven experiments, we show that both BBA$^+$ and MPC$^+$ outperform heuristics. Meanwhile, the proposed methods rival or outperforms Pensieve, with only 12%-33.22% of Pensieve's computation cost. Moreover, extensive results on real-world network environments demonstrate the superiority of proposed methods against existing approaches. Unlike previously AI-based methods, we collect a series of useful information via domain knowledge during the experiments, which helps improve the algorithms in a comprehensive and systematical way. In summeray, our contributions are listed as follows:

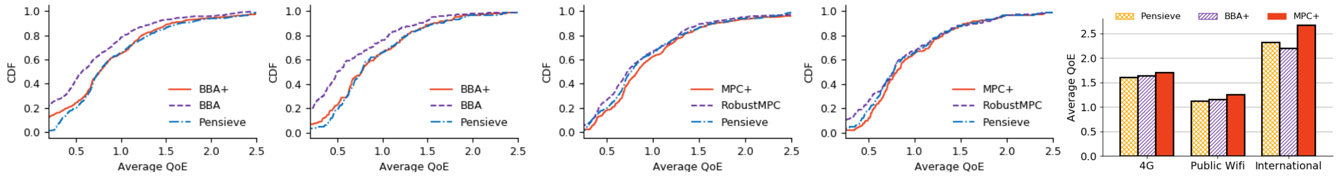
(1) To the best of our knowledge, we are the first to fuse AI methods and heuristics to tackle the ABR problem.
(2) Motivated by the aforementioned ideas, we propose BBA$^+$ and MPC$^+$. Results indicate that such interpretable schemes can achieve high performances and reduce computation costs.

2 DESIGN

In this section, we present BBA$^+$ and MPC$^+$, the ABR methods that utilize DL to improve conventional schemes.

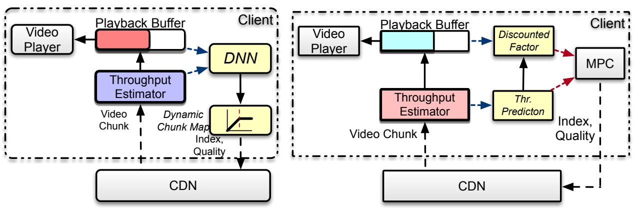
SIGCOMM Posters and Demos '19, August 19–23, 2019, Beijing, China

ACM ISBN 978-1-4503-6886-5/19/08…$15.00
https://doi.org/10.1145/3342280.3342291



(a) BBA$^+$ on FCC and HSDPA dataset. (b) MPC$^+$ on FCC and HSDPA dataset (c) Real-world Experiments

Figure 2: Comparing BBA$^+$ and MPC$^+$ with other ABR algorithms under FCC and HSDPA network traces. Results are plotted with CDF distributions. Meanwhile, we test the proposed methods in the wild.



(a) BBA$^+$ (b) MPC$^+$

Figure 3: BBA$^+$ and MPC$^+$ System Overview.

Table 1: Details of experimental results: including normalized QoE (QoE / QoE$_{optimal}$) and computation cost.

ABRs	Pensieve	BBA	MPC	BBA$^+$	MPC$^+$
FCC	0.908	0.638	0.860	0.859	**0.962**
HSDPA	0.912	0.630	0.864	0.871	**0.950**
Cost (KFLOPs)	298	-	-	**37**	99

BBA$^+$ Design. BBA [3] selects the bitrate via current buffer size. BBA$^+$ (Figure 3(a)) uses DNN to output a buffer-bound with the current state. Then it constructs a chunk map w.r.t the given buffer-bound and buffer occupancy. Finally, the next bitrate is selected via the current buffer size.

(1) **DNN Model.** BBA$^+$ takes the several signals to determine the suitable buffer-bound, including past throughput measured, download time for past sequences, previous video bitrate selected, video playback time remaining, current buffer occupancy, and the video sizes for next video chunk. We then leverage DDPG, a continuous deep reinforcement learning algorithm [4], to train BBA$^+$.
(2) **BBA Model.** We then generalize the concept of rate maps to chunk maps [3]. BBA$^+$ finally takes the next chunk's bitrate w.r.t the current buffer size.

MPC$^+$ Design. MPC [8] selects the bitrate via maximize QoE objectives. Inspired by recent work, we propose MPC$^+$, which leverages DL to accurately predict future throughput for improving the overall performance (Figure 3(b)). MPC$^+$ picks the bitrate for the next chunk $k+1$ as follows:

(1) **DL-based Throughput Predictor**, which utilizes DL to predict future throughput $1/C_{k+1}$ from past throughput vector C_k and past download time D_k.
(2) **Discounted Factor Optimizer**, which uses A3C [6], a deep reinforcement learning method, to determine the discount factor γ_k for chunk k, and calculates the final throughput predicted $\hat{C_k} = \gamma_k * C_k$. Considering the trade-off between NN's convergence time and performance, we pick *10* discrete actions to represent γ_k.
(3) **Conventional MPC Model**, which computes best bitrate R_{k+1} for maximize the given QoE objectives [8].

3 PRELIMINARY RESULTS

QoE Metrics. We use the general QoE metric QoE_{lin} to evaluate the proposed method as suggested by [5, 8].
Trace-driven Evaluation. We establish a full-system implementation, including a `dash.js` [1] video player, an ABR server, and an HTTP content server. We use mahimahi [7] to evaluate schemes via various network traces, including FCC and HSDPA. Figure 2(a) illustrates the CDF of QoE for the proposed schemes and baselines. We find that BBA$^+$ performs better than conventional BBA on the FCC and HSDPA dataset, with the improvements on average QoE of 34.27% to 38.28%. What's more, as listed in Table 1, although BBA$^+$'s performance is within 4.54%-5.74% of Pensieve across all network traces, BBA$^+$ only uses *12.4% of Pensieve's computation costs*. Meanwhile, we also analyze the performance of MPC$^+$ on same network traces. Results (2(b)) indicate that MPC$^+$ outperforms traditional MPC on the average QoE of 9.74% to 11.65%. We also show that MPC$^+$ surpasses Pensieve by 4.0% to 5.91%.
Real-world Implementation. We also set up a real-world experiment to evaluate BBA$^+$ and MPC$^+$ in the wild, including 4G/LTE network, WiFi network and international link. Results 2(c) indicate that MPC$^+$ and BBA$^+$ improve the average QoE of 5.59%-15.09% compared with Pensieve.
Interpretability. We have abilities to discriminate which module works relatively poor and change it, since each one has a clear sub-goal and can be explained.

4 SUMMARY AND FUTURE WORK

In this poster, we prove that the combination of heuristics and AI-based schemes can not only improve the performance but also keep it be easily explained. Additional research may focus on 1) generalizing an end-to-end NN model with the inspiration of heuristics. 2) design an interpretable model via learning from AI.
Acknowledgement. We thank the anonymous reviewers for their valuable feedback. The work was supported by the National Key R&D Program of China (2018YFB1003703), NSFC under Grant 61521002, Beijing Key Lab of Networked Multimedia No. Z161100005016051, and Alibaba-Tsinghua Joint Project (20172001689).

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