Fairness improvement by combination of ABR and TCP algorithms in ABR video streaming

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Abstract: MPEG-DASH (MPEG Dynamic Adaptive Streaming over HTTP) is an international standard for video playback. In MPEG-DASH, the user perceived performance of video playback is determined by the interaction of ABR algorithms on higher layer (application layer) and TCP algorithms on lower layer (transport layer). In this paper, we evaluate several promising combinations of ABR algorithms in the application layer and TCP algorithms in the transport layer and show that carefully selected combinations can improve fairness among users. And we identify specific features of combinations which bring improvement of fairness.

Keywords: DASH, congestion control, fairness
Classification: Network System

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1 Introduction

MPEG-DASH (MPEG Dynamic Adaptive Streaming over HTTP) [1] is an international standard for video streaming to deal with the increasing demand for video viewing. In MPEG-DASH, the client selects the bitrate of each segment by using an ABR (Adaptive BitRate) based on its available bandwidth or buffer occupancy [10]. ABR algorithms operate in the application layer of clients. MPEG-DASH utilizes HTTP, so it uses TCP in the transport layer. This means that the download throughput is obtained as a result of both ABR and TCP algorithm’s transmission rate adjustment, so the user perceived performance of video playback is determined by the interaction of ABR and TCP algorithms.

There have been many proposed TCP algorithms [2, 3], and default TCP version is generally different for the end host OS. When flows implementing different TCP algorithms share the same bottleneck link, there is an unfairness problem that results in differences of the flow throughput [4, 5]. As mentioned above, unfairness between the TCP algorithms affects the behavior of the ABR algorithm at the application layer, which might result in a significant impact on the user-perceived performance through the application layer.

We investigated the possibility that a combination of TCP and ABR algorithms could improve the unfair condition between the TCP algorithms observed at the transport layer by the behavior of the ABR algorithm in the application layer [6]. Our evaluation results [6] show that the combination of PANDA (Probe AND Adapt) [7] + CUBIC [4] and BBA (Buffer Based Approach) [8] + CTCP (Compound TCP) [5] can improve fairness between CUBIC and CTCP flows. When PANDA (Probe AND Adapt) [7] is used in the application layer, transmission timing of the next segment is adjusted to stabilize the buffer level (this function is called “scheduling” in [7]), so there is Off-period (short interval without any segment transmission) just after the end of each segment transmission. The reason of fairness improvement is that CTCP flow can improve its throughput by increasing its window size during Off-period of CUBIC flow.

In this paper, we investigate more combinations of ABR and TCP algorithms. We
newly focus also on FESTIVE [9] as one of ABR algorithms. FESTIVE takes account of fair bitrate selection for multiple clients. Totally, we comparatively evaluate user-perceived performance of bitrate selection and transport layer performance of congestion window size for ABR algorithms of PANDA, BBA (Buffer-Based Approach) and FESTIVE. For TCP versions, we focus on CUBIC and CTCP, which are major deployed TCP versions and are well-known to have fairness issues in the transport layer. Based on a number of our careful evaluation results, in this paper, we newly find that the combinations of (a moderate ABR algorithm with Off-period + an aggressive TCP) and (an aggressive ABR without Off-period + a moderate TCP) can contribute fairness improvement.

2 Fairness issues of ABR and TCP algorithms

It is well-known that different TCP versions have fairness issues when they share the same bottleneck link [4, 5]. For example, throughput of CTCP flow is significantly lower than CUBIC. However, fairness issues for TCP flows have been generally investigated for greedy model, where the application layer can always send out data to the transport layer when necessary. It has not been clearly investigated whether bitrate selection of ABR in the application layer also holds fairness issues transparently from the transport layer.

We evaluate bitrate selection of ABR in the case that CTCP flow and CUBIC flow share the same bottleneck link. Due to space limitation, we omit evaluation results, but our evaluation for PANDA with CTCP flow and PANDA with CUBIC flows show that bitrate selection of ABR algorithm in the application layer also shows unfairness between CTCP and CUBIC flows. We also evaluate the cases for BBA and FESTIVE and these results also show that fairness issues are still held in the application layer.

3 Performance evaluation for combination of ABR and TCP

We have evaluated many combinations of ABR and TCP algorithms, e.g. (PANDA, BBA, FESTIVE) * (CTCP, CUBIC). In this paper, due to space limitation, we would like to focus only on results of combinations which can improve fairness (for comparative discussion, we also show some results which has unfairness issues).

3.1 Application layer view

In this subsection, we evaluate the fairness improvements of the combination of ABR and TCP algorithms especially from the application layer view. Specifically, we compare the case of clients using the same ABR algorithms (PANDA, FESTIVE) with different TCP algorithms, and the combination of (PANDA + CUBIC flow, BBA + CTCP flow) and (FESTIVE + CUBIC flow, BBA + CTCP flow). We use ns3 [11] for our evaluation. Our evaluation model is the dumbbell topology that a CUBIC flow and a CTCP flow share the 6 [Mbps] bottleneck link. Total round trip time of the dumbbell model is 120 [ms]. The buffer size of the router was set to 60 [pkt] which is BDP (Bandwidth Delay Product), and the packet size is set to 1500 [bytes]. The parameters used for CUBIC, CTCP, PANDA and BBA are set to the default values used in [4, 5, 7] and [8], respectively. Duration of the video is 636 [s] and the
segment size is 2 [s]. The video is encoded in ten steps from 0.459 to 11.321 [Mps], according to [7]. Figure 1(a) and (b) show the bitrate difference of each user related to PANDA and FESTIVE, respectively. The bitrate difference is defined as follows.

\[
\text{bitrate difference} = \int_0^T \left( f_{\text{cubic}}(t) - f_{\text{ctcp}}(t) \right) dt
\]

(1)

\( f_{\text{cubic}}(t) \) and \( f_{\text{ctcp}}(t) \) is the selected bitrate at time \( t \) by the CUBIC and CTCP client, respectively. \( T \) indicates the earliest download completion time of the CUBIC and CTCP clients.

![Fig. 1. Bitrate difference of each user](image)

From Fig. 1(a) and (b), PANDA and FESTIVE show bitrate unfairness of the application layer whose indirect reason is the unfairness in the transport layer. In contrast, the combinations of (PANDA + CUBIC flow, BBA + CTCP flow) and (FESTIVE + CUBIC flow, BBA + CTCP flow) can improve the bitrate fairness. To investigate this reason, we focus on aggressive or moderate estimation of ABR algorithms. Figure 2(a), (b), (c) and (d) show the throughput and selected bitrate of each segment of PANDA + CUBIC flow, BBA + CTCP flow, FESTIVE + CUBIC flow and BBA + CTCP flow, respectively.

From Fig. 2(a) and (c), PANDA and FESTIVE select moderate bitrate against observed throughput of each segment. In contrast, from Fig. 2(b) and (d), BBA selects aggressive bitrate against the throughput. The difference between ABR and TCP algorithm’s aggressiveness, i.e. aggressive ABR + moderate TCP and moderate ABR + aggressive TCP improve fairness of selected bitrate.

### 3.2 Transport layer view

In this subsection, we show congestion window size and Off-period of each flow in order to investigate the fairness improvement in TCP. Figure 3 shows the congestion window of each flow. Green lines in Fig. 3 show Off-Period of PANDA and FESTIVE.

From Fig. 3(a), BBA + CTCP flow increases its congestion window size during Off-period of PANDA + CUBIC flow. This is the reason why the combination of Fig. 3(a) can improve fairness of transport layer as investigated in [6]. From Fig. 3(b), the mechanism of fairness improvement also observed in the case of FESTIVE. These results also confirm that the combination of a moderate ABR
algorithm with an aggressive TCP algorithm and an aggressive ABR algorithm with a moderate TCP algorithm can improve fairness.

4 Conclusion

In this paper, we evaluated combinations of ABR and TCP algorithms that improve fairness of multiple flows with different TCP algorithms. We categorize TCP algorithms and ABR algorithms in two categories, i.e. aggressive and moderate. For TCP algorithms, CUBIC is aggressive TCP because it outperforms CTCP. For ABR algorithms, BBA is aggressive because it selects rather closer bitrate to measured throughput. And PANDA and FESTIVE are categorized to moderate because its bitrate is a little lower than the measured throughput. Our evaluation results show that the combination of a moderate ABR algorithm with an aggressive TCP algorithm and an aggressive ABR algorithm with a moderate TCP algorithm can improve fairness. In future work, we plan to propose an ABR algorithm that improves fairness.
in the case of multiple clients utilizing same ABR algorithms with different TCP algorithms.

**Acknowledgments**

This work was partly supported by JSPS KAKENHI Grant Number 17H01740.