Conducting Rate-Distortion Optimization in Data-Driven P2P Video Streaming

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ABSTRACT

The configuration of received chunks is the key to the video playback quality. The lack of more important chunks could degrade playback quality significantly. Unfortunately, directly applying rate-distortion (RD)-first or importance-first scheduling strategy in data-driven P2P streaming could incur serious content bottleneck problem. In this work, we first identify this new content bottleneck problem and propose a simple strategy-switching approach to soften the unique phenomenon so as to further improve playback quality.

Categories and Subject Descriptors

C.2 [Computer-Communications Networks]: Distributed Systems-Distributed Applications.

General Terms

Design, Performance.

Keywords

Peer-to-peer streaming and rate-distortion optimization.

1. MOTIVATION

Media chunk scheduling is the core of data-driven (swarming-based) P2P streaming [1-4]. Each peer decides which absent chunk should be requested from which neighbor according to surrounding chunk availability. Existing works [1-3] take rarest-first strategy to make each peer's chunk availability as diverse as possible so that each peer can better play a load balancing role in the system. Zhou *et al*. [2] partition the set of to-be-requested chunks into two parts: one is for deadline-first and the other is for rarest-first. A hybrid rarity-deadline strategy-switching approach is adopted to improve the system throughput so as to smooth playback quality. Zhang *et al*. [3] predict maximum rate, at which each peer can deliver and prioritize each chunk according to rarity function and emergency function. A distributed min-cost flow decision process is applied to improve system throughput. All of works [1-3] regard each video chunk as equal-important unit and aim to increase the bandwidth utilization and optimize system throughput. Note that maximizing the system throughput is not exactly corresponding to the received video quality. Each chunk has different importance impact (or distortion impact) on the video. The lack of more important chunks, e.g. the chunks with the property of synchronization or as a part of high-motion frame, could degrade playback quality significantly. Therefore, maximizing *the throughput of important chunks* is the key to the playback quality [5]. Although the traditional client-server/multi-server models [5] have given much attention to this rate-distortion problem, their solutions do not work in data-driven P2P streaming. This is because that the server owns all contents. There is no data availability problem in client-server/multi-servers model. Hence, if we directly apply rate-distortion/importance -first strategy (instead of rarity-first or hybrid rarity-deadline) in data-driven P2P streaming, a serious content bottleneck problem [6] could happen since all the peers under their local view would like to get the most important chucks for themselves. Moreover, such rate-distortion-first strategy results in wasting lots of outbound bandwidth, which could be effectively used for other chucks dissemination. Hence, how to realize rate-distortion optimization in data-driven P2P streaming [6] is a challenging and interesting problem, and it is the focus of this work.

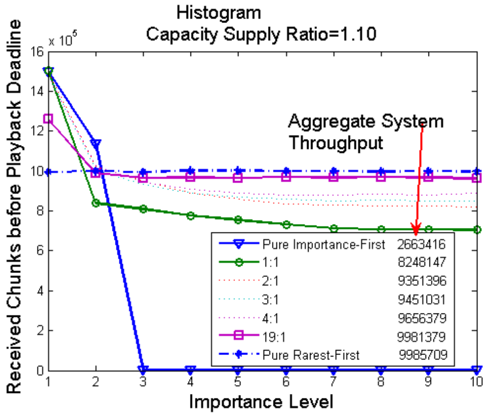

Figure 1: System throughput with different switching patterns between rarest-first and importance-first strategy

2. METHODOLOGY

We use event-driven packet-level simulator in [3] to study different scheduling strategies individually, and all of them are based on the distributed min-cost flow framework [3]. We use three types of nodes (500 nodes) whose outbound capacities are 1Mbps, 384kbps and 128kbps respectively and inbound capacities are greater than 300kbps. The *capacity supply ratio* is used to represent the system capability, which is defined as the ratio of average outbound capacity to the raw streaming rate (300 kbps). Buffer maps are exchanged periodically to notify new available chunks among peers. Each peer contacts with 15 neighbors. Term *system throughput* is defined to represent the number of chunks arrival before playback deadline. In all experiments, the outbound capacity of each peer is uniformly allocated to its neighbors. Each experiment is running for 1,000 seconds. We classify the system throughput according to *10* importance levels as shown in Fig. 1. Level 1 is the most important one for the reconstruction quality. We can see that the system throughput for importance-first strategy is mostly contributed by chunks of importance level 1 and level 2. On the contrary, the distributions of the system throughput for rarest-first and deadline-first scheduling strategy appear quite uniform. Moreover, the system throughput of both importance-first and deadline-first are much lower than the case of rarest-first strategy. This is because the rarest-first strategy is to let each peer request the rarest duplication to adaptively balance the distribution of each chunk. Thus, the rarest-first strategy can provide more diverse chunk configuration for streaming than others. So, such a strategy can increase the opportunity for playing a load balancing role in the system. Further, the whole system bandwidth can be leveraged. On the contrary, directly using importance-first strategy in data-driven P2P streaming could exacerbate inherent content bottleneck phenomenon in P2P streaming system [6]. This is because all peers aggressively request the most important chunks for themselves. Such a distributed strategy might induce that all duplication in the streaming system appear similar, i.e. concentrating on the same level, as shown in Fig. 1. Thus, the newly generated chunks are exactly invisible and could not be scheduled into each chunk subscription process. Consequently, all peers lose the opportunity for contributing its own outbound bandwidth. Note that the similar observation could be made for the deadline-first strategy. Unlike the importance-first strategy, on performing the rarest-first or deadline-first strategy, no prior importance is associated to each chunk. Each chunk gets the same request precedence statistically with others before its playback. This also explains why the throughput distributions of rarest-first and deadline-first scheduling strategy are uniform.

From the above discussion, we note that the importance-first strategy could maximize the throughput of important chunks but it has a poor system throughput. Here comes the challenging issue: *how can we maximize the throughput of important chunks without degrading the system throughput*? To cope with this issue, we adopt the strategy-switching approach [2]. For example, 1:1 interlaced rarest-first and importance-first strategy is used for the P2P streaming system. Surprisingly, the system throughput, as shown in Fig. 1, is significantly upgraded. In addition, the throughput of level-1 chunks just degrades little. With the increase the ratio of the percentage using the rarest-first strategy to the percentage using the importance-first strategy, we can see that the system throughput is getting closer to that of the original rarest-first strategy. This observation indicates that there exists tradeoff between rarest-first and importance-first strategy. In addition, the system throughput can be reshaped by simple switching between rarest-first and importance-first strategy without degrading the system throughput, which is very useful for quality-oriented P2P streaming system. Therefore, we are motivated to drive the rate-distortion optimization in data-driven P2P system.

Rate-Distortion Hint Track [5] is a very efficient but simple importance-labeling approach. By this approach, each chunk can be easily classified into different RD clusters with a weighting coefficient α_i, which is an average statistic rate-distortion benefit. Hence, our proposed strategy-switching approach can be jointly designed with this video coding technique. That is, we formulate the system rate-distortion optimization as follows:

$$\pi^* = \arg_{\pi} \mathrm{Max} \sum_{i} \alpha_i \cdot N_i \ , \mathrm{s.t.} \sum_{i} N_i \leq S$$

, where N_i is the throughput of level *i*, S is the system capability upper bound and $\pi \in [0,1]$ is the percentage of using the importance-first strategy. This rate-distortion optimization is to figure out a π^* such that best system video quality can be achieved. In the future, we will provide a theoretical analysis for our observation and try to develop a dynamic switching approach for each peer to adapt network conditions, e.g. (1) the location in overlay (2) peer churn (3) heterogeneous peer capability, so as to further improve playback quality.

3. REFERENCES

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