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Towards efficient video chunk dissemination in peer-to-peer live streaming

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ABSTRACT

There are substantial differences in chunk dissemination manner between P2P live streaming and BitTorrent, and inappropriate algorithms will result in inefficiency of live streaming systems. In this paper, we study the chunk dissemination of P2P live streaming, and introduce a discrete and slotted mathematical model to analyze chunk selection algorithms, including rarest first algorithm and greedy algorithm. Moreover, we present a performance metric to evaluate chunk selection algorithms, as well as the optimization function for the exploration of chunk dissemination strategies. We point out the causes of poor performance of these algorithms, and propose a service request randomization mechanism to promote the use of peer resources, which can prevent chunk requests from rendezvous on a few of peers. Simultaneously, we employ weight assignment strategies to avoid excessive requests for rare chunks. Besides, we present an enhanced model, which adds node degree constraint, to improve our model. We revisit the chunk selection algorithms based on the enhanced model. The results of simulation experiments validate our theoretical analysis and indicate that the weighted randomization mechanism is resilient to flash crowd and peer churn, and can improve the performance of P2P live streaming.

1. Introduction

Transmitting television signal over Internet has become a popular multimedia application. To achieve high performance with low cost, service providers usually employ peer-to-peer (P2P) scheme. According to the characteristic of scheduling mechanisms, P2P live streaming systems can be classified as pull-based or push-based. In pull-based P2P live streaming, end users, also called peers, are organized to construct a mesh overlay network in application layer while video streaming is divided into chunks. Subsequently, each peer periodically sends buffer map packets to notify all its neighbors what chunks it has in the buffer, and then these video chunks are distributed and exchanged in the mesh overlay network. During the chunk dissemination, peer's bandwidth is utilized for uploading, which remarkably decreases the pressure of streaming server. Currently, most of live streaming systems deployed in the Internet, such as Coolstreaming [1], PPLive [2], PPStream [3], adopt pull-based P2P scheme to distribute video chunks.

From the perspective of technology, peer resources in P2P network can be sufficiently exploited only if there are abundant content or chunks that other peers are interested in, and higher chunk diversity between peers' buffers means that each peer has more chunks that other peers are interested in, hence the potential capabilities of parallel downloading among peers are greater. For example, rarest first algorithm [4], which is proposed by Cohen and applied in BitTorrent, promotes the dissemination of rare chunks and increases the chunk delivery rate in P2P file-sharing network.

Although there are some similarities in chunk dissemination manner between P2P live streaming and

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BitTorrent, P2P live streaming is substantially different from BitTorrent, because live streaming is delay-sensitive, and all video chunks must arrive at peers' buffers before they are played, otherwise they will be missed. Therefore, applying the scheduling algorithm of BitTorrent to live streaming may cause inefficient chunk dissemination, because the streaming server in live streaming system will periodically generate new video chunks, and these chunks are apparently rarer than those old ones. In this case, lots of peers will send requests for these new chunks without considering the playback deadline urgency of video chunks, which will increase chunk missing ratio and worsen the quality of user experience. On the other hand, if peers schedule chunks merely according to the playback deadline, chunk diversity between peers' buffers will decrease extremely, and the utilization of peer resources will also be restricted. Besides, flash crowd is an important issue for live streaming. When some popular programs start, many users will access this channel during a short time, and if these requests could not be handled appropriately, severe performance problem will emerge. Another crucial issue is peer churn, and robust live streaming systems must have the capability against peer dynamics. Practical chunk scheduling mechanisms must be able to deal with these issues.

In this paper, we focus on the chunk scheduling and dissemination of pull-based P2P live streaming, and our contributions are as follows:

- We present a basic mathematical model for the analysis of chunk dissemination, and introduce a performance metric to evaluate chunk selection algorithms. Moreover, we propose the objective function to optimize the chunk dissemination of P2P live streaming.
- Based on the basic model, we analyze the performance of deterministic chunk selection algorithms, including rarest first algorithm and greedy algorithm, and point out the reasons of inefficient chunk dissemination. Subsequently, we propose two approaches to improve the performance of chunk selection algorithms.
- We employ service request randomization to optimize the chunk selection algorithms, and introduce a left-skewed weight assignment strategy. Moreover, we propose another two strategies, namely even strategy and right-skewed strategy, to validate our analysis results.
- We add node degree constraint to a new enhanced model, which makes our model closer to the realistic system. Based on the enhanced model, we revisit the two types of chunk selection algorithms, and derive more accurate results. Finally, we evaluate the performance of weighted randomization mechanism via simulation experiments.

The remainder of this paper is organized as follows. Section 2 outlines related work. Section 3 presents the basic mathematical model of chunk dissemination and the performance metric. Section 4 analyzes deterministic chunk selection algorithms, and proposes weighted randomization mechanism to improve the performance of live streaming. Section 5 improves the basic model and presents an enhanced model to achieve more practical results. Section 6 introduces the simulation experiments and performance evaluation on different algorithms. Finally, Section 7 presents the conclusions of our work.

2. Related work

It is difficult and costly to implement large-scale live streaming system only depending on server's bandwidth resources, so it is an alternative solution to adopt P2P scheme to exploit end users' resources. When P2P scheme is employed in live streaming system, the structure of overlay network and resource scheduling mechanism should be designed carefully. In [1], the authors firstly introduced P2P scheme into a practical live streaming system, and proposed a data-driven based overlay network, namely DONet, to disseminate video chunks. In [6], the authors studied pull-based P2P-TV systems, and provided the guidelines for overlay topology design and chunk scheduling algorithms. In [11], the authors analyzed the existence and importance of stable peers, and then proposed a tiered overlay design. In [20], the authors explored a proactive strategy to construct churn-aware overlay network, and it could mitigate the impact of peer churn. In [10], the authors pointed out that the optimality of pull-based protocol came from a cost-tradeoff between control overhead and delay, and they proposed a pull–push hybrid protocol. In [7], the authors proposed a deadline-aware scheduling mechanism, in which those chunk requests with urgent deadline had greater priority, and they also adopted early drop to reduce the resource waste. In [16], the authors modeled the scheduling issue in data-driven streaming system as a min-cost network flow problem, and proposed a distributed heuristic algorithm for system optimization. In [5], the authors presented a mixed strategy, which combined rarest first strategy with greedy strategy, and it achieved better performance. In [19], the authors studied the chunk distribution in unstructured P2P streaming, and presented the formal proof that there existed a distributed scheduling strategy being able to achieve the minimum steps to distribute a chunk. In [12], the authors employed the density dependent jump Markov process to analyze chunk selection policies, and they claimed that the optimal policy was V-shaped, i.e. urgent or rare chunks should be selected firstly. In [14], the authors proposed to select receiver with a probability which was proportional to the upload bandwidth of peers. In [13], the authors presented a novel metric, called the Content Propagation Metric (CPM), to quantitatively evaluate the marginal benefit of available bandwidth, and CPM could guide a global allocation of bandwidth to maximize the aggregate download bandwidth of consumers. In [15], the authors employed random network coding into practical live streaming system, namely UUSee, and it improved the chunk distribution. In [8], the authors proposed a view-upload decoupling framework to enable cross-channel resource sharing, which ensured resource provision was sufficient for user demands in each channel. In [17], the authors analyzed the resource scheduling mechanism in