Journal of Network and Computer Applications 45 (2014) 1–14

Contents lists available at ScienceDirect

Journal of Network and Computer Applications

journal homepage: www.elsevier.com/locate/jnca

Efficient content delivery scheme for layered video streaming in large-scale networks

Abbas Bradai [a], Toufik Ahmed [a], Raouf Boutaba [b,*], Reaz Ahmed [b]

[a] CNRS-LaBRI, University of Bordeaux, 351, Cours de la Libération, Talence Cedex, France
[b] School of Computer Science, University of Waterloo, 200 University Avenue W., Waterloo, ON, Canada

ARTICLE INFO

Article history:
Received 29 January 2014
Received in revised form
2 May 2014
Accepted 14 July 2014
Available online 22 July 2014

Keywords:
Content distribution
Bandwidth allocation
Scheduling
P2P
Layered video
QoS

ABSTRACT

Providing efficient layered video streaming to heterogeneous users in varying network conditions requires dynamic bandwidth allocation, efficient data scheduling and incentives. In layered streaming, the video stream is composed of hierarchically encoded sub-stream layers namely the base layer and enhancements layers. We consider a scenario where receiver peers use a pull-based approach to adjust the video quality level to their terminal and network capacities by subscribing to a different number of layers. In this context, in order to take advantage of the available bandwidth in the network and to enhance end users Quality-of-Experience (QoE), we propose a novel approach that efficiently allocates sender peers' upload bandwidth to receiver peers. The upstream peer bandwidth is allocated depending on the quality level (requested layers) of the receiver peers, starting by allocating bandwidth for the lower layers first. In order to allocate bandwidth for a certain layer, an auction game is established to distribute the bandwidth among the receiver peers, where the sender peers "sell" their items (upload bandwidth) according to bids submitted by receiver peers. The main goal of this approach is to favor high priority peers while ensuring a minimum quality level to all peers. The proposed bandwidth allocation mechanism is paired with efficient scheduling mechanism for layered streaming. It aims to fully take advantage of the allocated bandwidth while respecting the layers dependency of the stream and the data blocks playback deadline. Extensive evaluations are conducted to compare our proposed algorithm with other bandwidth allocation strategies for layered video streaming. The obtained results show the effectiveness of our model in terms of video quality, useless chunks ratio and bandwidth utilization under different network/streaming conditions.

1. Introduction

Recent years witnessed a spectacular increase in demand for customized video streaming services. For a large part, this demand is characterized by the wide availability of wireless access networks and the proliferation of various mobile devices (e.g., smart phones, tablets, gaming consoles, etc.) with different CPU, memory, and network capacities.

Layered video streaming, such as Scalable Video Coding (SVC) (Cheng-Hsin and Hefeeda, 2008), provides a convenient way to perform video quality adaptation to adjust to the end device heterogeneity and changing network conditions. Layered video streaming consists of a base layer and multiple enhancement layers. Receivers can adjust the video quality level to their capability by subscribing to a different number of layers.

Besides, using peer-to-peer overlay has become more and more popular approach for streaming video content over the Internet due to its high scalability and facility of deployment. In P2P streaming, peers actively contribute their resources (mainly upload bandwidth) by forwarding their available content to their connected peers. Since the cumulative available resources in this approach grow with the user population, this approach can scale with the number of joining peers in the session.

Thus, streaming a layered video over P2P architecture is promising approach for scalable video delivery to a large number of heterogeneous receivers (Guo et al., 2009; Liu et al., 2009; Ramzan et al., 2011). An example of such architecture is provided in Fig. 1. In this example the video source streams a layered video composed of three layers. The peers subscribe to number of layers depending on their capacities and each receiver peer becomes in its turn sender peer by serving one or many layers.

1.1. Motivations

In P2P video streaming systems, the content retrieval mechanism allows a user to receive streaming data blocks (chunks) from

* Correspondence to: Cheriton School of Computer Science, University of Waterloo, 200 University Avenue West, Waterloo, Ontario, Canada N2L 3G1. Tel.: +1 519 888 4820.
E-mail addresses: bradai@labri.fr (A. Bradai), tad@labri.fr (T. Ahmed), rboutaba@uwaterloo.ca (R. Boutaba), r5ahmed@uwaterloo.ca (R. Ahmed).

http://dx.doi.org/10.1016/j.jnca.2014.07.004
1084-8045/

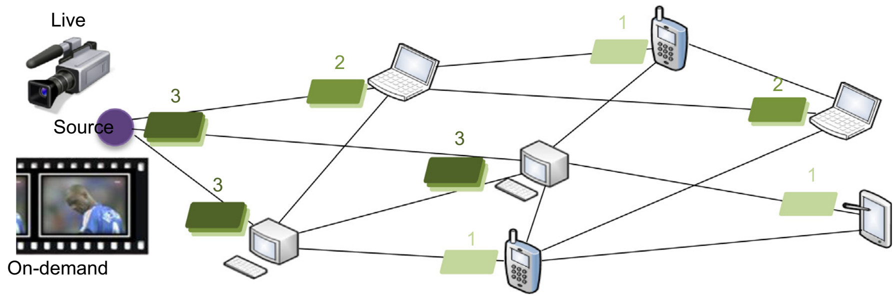

Fig. 1. Example of P2P layered streaming architecture.

other peers using the constructed overlay. This mechanism plays a leading role in the video streaming process and its efficiency influences the global performance.

Efficient chunks scheduling and appropriate bandwidth allocation are the two significant challenges of the content retrieval mechanism for real-time P2P streaming systems. The two components cannot be dissociated each from the other. Indeed, a good exploitation of the sender peers' bandwidth cannot be reached without optimized scheduling scheme. Reciprocally, an efficient scheduling algorithm cannot achieve a good throughput without appropriate sender peers' bandwidth allocation mechanism.

While considering the dynamicity of peers in terms of joining/leaving the network, the heterogeneity of peers and their need for bandwidth, an efficient and dynamic mechanism for bandwidth allocation is required to ensure the timely availability of the streaming content and acceptable quality level for peers while fully taking advantage of the overall bandwidth in the network.

In the context of pull-based layered streaming over P2P architecture, a peer commonly requests video layers from different upstream peers, and each upstream peer shares its upload bandwidth among different downstream peers serving different layers. Consequently, resolving bandwidth conflicts among peers in order to maximize the benefits of both upstream and downstream peers is a very challenging problem, because of the layers importance, their dependencies and the peers' priorities.

On the other hand, the scheduling task is complicated in the context of layered video streaming since chunks received after their playback deadline are not played and considered as useless chunks. In addition, chunks of higher layers received without their corresponding chunks from higher layers are not played also and considered as useless too.

Moreover, selfishness of peers in P2P networks is inevitable (Park and van der Schaar, 2010). Therefore, a key research question to consider when designing streaming system in P2P architecture is: "How to exploit and manage the selfishness of peers in order to reduce the global streaming cost while satisfying the peers quality level requirements and priorities?"

Most related works considered one or two of the three components of the content delivery mechanism of the P2P layered streaming systems: bandwidth allocation, the chunks scheduling or the incentives. But no one considered the three issues all together, which is particularly challenging for efficient P2P streaming. Hence, the main challenge in this work is how to allocate the upstream bandwidth among its downstream peers (see Fig. 2) while fully taking advantage of the available bandwidth in the network and handling the peers selfishness to ensure the better video quality for all peers.

In our previous work (Bradai and Ahmed, 2012a), we presented an efficient chunks scheduling mechanism for P2P layered streaming systems. In this work, we mainly focus on the bandwidth allocation and the incentive mechanisms.

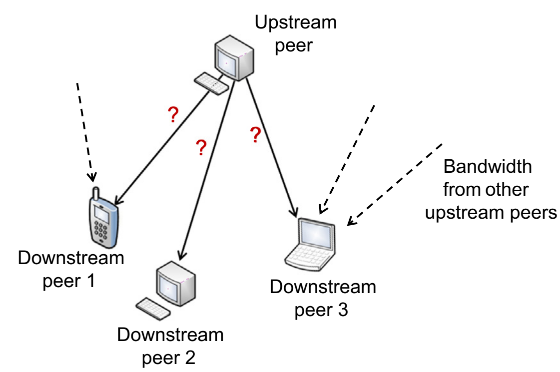

Fig. 2. Example of upstream peer bandwidth allocation problem.

1.2. Contributions

Recently there have been significant research efforts on designing P2P architectures by addressing the selfishness of peers. They can be categorized into two main approaches: "non-strategic behavior approach" such as Ma et al. (2004), Wang and Li (2005), Cui et al. (2006) and "strategic behavior approach" such as Takahashi and Tanaka (2001), Chun et al. (2005). In the former, each peer is considered as a potential game player aiming at maximizing its utility regardless of the behavior of other peers, while in the later each peer aims at maximizing its utility taking into consideration the actions of the other peers. In this paper, we propose a novel strategic and incentive model for efficient bandwidth allocation in P2P layered streaming networks.

Our main contributions in this paper are as follows:

(1) Auction game model for bandwidth allocation in P2P layered streaming is proposed. The players in this game are the upstream peer which sell its upload bandwidth and on the hand the downstream peers which bids for. The proposed model is content aware and an auction game is set up for each layer.
(2) Water filling algorithm based downstream peer bidding strategy is proposed. It aims to request the stream from the best links in terms of QoS metrics such as packet loss ratio and end to end delay.
(3) A theoretical study of the proposed mechanism is provided and the Nash equilibrium of the system is proved.
(4) Extensive simulations are conducted to show the performance enhancement of our mechanism using SVC video sequences and real P2P streaming system traces.