論文の要旨

A Study on High Quality and Low Cost Peer to Peer Live Streaming over Internet

（インターネット上のP2Pライブストリーミングの高品質化・低コスト化の研究）

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Recently, Peer to Peer (P2P) systems have been widely leveraged to broadcast a live video stream to a large number of viewers. In P2P live streaming, peers (viewers) not only watch the stream but also contribute their resources to share it. As a result, this collaborative approach reduces the cost and improves the scalability of the traditional client-server live streaming systems. However, P2P systems work in a best-effort manner and depend on the voluntary contribution of resources. Accordingly, it is challenging to provide a high quality of streaming service (QoS), i.e., smooth playback and short delay, in the pure P2P. To achieve that, it is important to solve two key issues as follows: 1) how to maximally utilize resources of participant peers to share a live stream, and 2) how to improve the reliability of P2P systems by the assistance of reliable servers with a low cost.

In this thesis, we tackled the above-mentioned two issues and provided answers for them. At first the problem of maximally utilizing resources of participant peers is approached to improve the QoS in a pure P2P. Then, to guarantee the QoS, the hybrid of P2P with the reliable cloud platform is studied. In addition, the cost of the hybrid scheme is considered to be as low as possible without affecting the QoS. The thesis is organized as follows.

In the first chapter, research problems are introduced along with the contribution of the study presented in the thesis.

In the second chapter, a background of the P2P live streaming including the performance and cost is introduced. Several state-of-art works are reviewed for that purpose. Specifically, the chapter introduces:

- Different types of P2P live streaming overlays.
- Content distribution methods in P2P live streaming.
- Performance bounds of P2P live streaming.
- Hybrid CDN-P2P and cloud-P2P live streaming models.

In the third chapter, a new scheme is proposed to attain the maximal of resource utilization in a pure P2P. It was achieved by developing an efficient peering and content scheduling strategy. That strategy takes both upload bandwidth bottleneck and content bottleneck issues of P2P systems into account. In the proposed scheme, peers are organized in a multiple-tree overlay. That means a peer can be a parent delivering a part of streaming data (a substream) to other peers (its children), or a child receiving substreams from other peers (its parents) or both of them. The scheme, with the aid of a budget-model, allows peers to exchange money (upload bandwidth) by transferring the children to each other. The newly joined peer will quickly contribute to the video distribution

process, i.e., spends its money. Exchanging the children is done in such a way that guarantees a high number of peers forwarding exactly one substream to their children and that the trees have a short hop-count delay. By maximally utilizing the resources, verified by simulation results, the scheme is able to deliver a maximal streaming rate with a short delay. Moreover, results indicate that the proposed scheme gives nice features in the homogeneous scenario (i.e., all peers have an equal upload bandwidth) and overcomes conventional schemes in all simulated scenarios.

In the fourth chapter, the pure P2P system is assisted by the reliable cloud computing, having a hybrid cloud-P2P, to provide a guaranteed quality of service. The P2P overlay adopted is similar to the one adopted in Chapter 3, i.e., the multiple-tree overlay. In fact, it is hard to guarantee the quality of service in a pure multiple-tree P2P where peers join/leave the system or fail dynamically (peer churn). In the proposed cloud-P2P live streaming model, cloud storage and cloud content delivery network (CCDN) services are exploited to assist peers to maintain a smooth playback. The assistance is achieved by storing the latest streaming chunks in the cloud storage service. Then, each peer is allowed to fetch missing chunks from the storage service through edge locations of the CCDN. As cloud services are not free, such assistance incurs additional cost comprised of the amount of data fetched from the CCDN and the number of requests handled by the cloud. We proposed three techniques to reduce the cost of such a cloud assistance and evaluate them through extensive simulations.

- In the first technique, we exploited the cloud storage service to reduce the time for orphaned peers (who lost their parents) to find new parents in the delivery tree. That significantly reduces the system cost while incurs additional requests handled by the storage service.
- In the second technique, several internal nodes are selected from each tree to proactively fetch chunks from the CCDN. The selected node (peer) plays the role of a root for the corresponding tree, which reduces the height of the delivery tree and the load of other internal nodes
- Finally, the third technique reduces the number of requests handled by the CCDN in the second technique by allowing peers to request a collection of chunks, called frames, instead of individual chunks.

The simulation results indicate that the proposed method reduces the monetary cost of conventional cloud-assisted P2P by reducing the total amount of data fetched from the cloud by 42% and the total number of requests issued to the cloud by 66%. Along with that, due to the assistance of the cloud, the proposed method is able to guarantee the quality of live streaming service.

Finally, in the fifth chapter, the thesis is concluded with future work. It is pointed out that our work could be refined by dividing the video stream into multiple-rate substreams or by considering other metrics such as the stability and location of peers.