Report- and Reciprocity-Based Incentive Mechanisms for Live and On-Demand P2P Video Streaming

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Abstract. The popularity of video streaming in the Internet has continuously increased and traffic generated by such applications has become a large portion of the Internet traffic. The Peer-to-Peer (P2P) approach is becoming popular due to better scalability and reduced distribution cost. Live streaming and Video-on-Demand (VoD) are two fields of video streaming which have been treated as completely different; they are, however, from a user's point of view, very similar. Users of a P2P system already successfully collaborate on distributing video streams, thus, allowing for an integrated collaboration by having peers store video streams watched in the past to enable their distribution in the future. Since key P2P properties, such as scalability and cost savings, depend on the effectiveness of the underlying incentive mechanism, this paper (1) proposes *report* and *reciprocity-based* incentive mechanisms as candidates to address the proposed scenario and (2) outlines major requirements to meet.

1 Introduction

In the context of *video streaming*, *live streaming* and *Video-on-Demand* (VoD) are differentiated; while the former provides the delivery of video streams of live events, such as sport events, music concerts, and breaking news, the latter provides the distribution of recorded content, such as movies. While different in technical nature and in terms of implementation, from a user's point of view they are very similar. Since users of a P2P system already successfully collaborate on distributing video streams, the new idea of LiveShift [3] is to allow for an integrated collaboration by storing those video streams that users have watched in the past in order to enable these users to distribute them in the future. With the combination of live and on-demand video streaming users will be able to, without having previously prepared any local recording, watch the match or the Olympics from the start and jump over uninteresting parts until he/she seamlessly catches up with the live stream. Similarly, the live transmission may be used for the premier of a movie or TV show, when it is expected that several people watch at the same time. Instantly and automatically it will be available — since the starting time of the premier — to every user who joins at a later time. Major advantages for broadcasters are less administration efforts in recording and distributing video streams, since it is done automatically, and bandwidth and storage savings occur.

To address scalability problems of client-server solutions, to reduce financial costs, making video streaming distribution feasible for small content providers, even private end-users, P2P-based video streaming solutions have appeared. However, the presence of *free-riders* — peers that do not contribute resources to the network — undermines the potential scalability and cost-savings of the P2P approaches. *Incentive mechanisms* have been proposed to address this *fairness* problem by motivating peers to contribute resources and act fairly towards other peers. Up to now no fully integrated incentive mechanisms especially addressing this live streaming combination. A peer that has recorded video streams needs an incentive to keep the copy and provide it to other peers without necessarily being simultaneously interested in streams it can return to the P2P community. Thus, *report-based* and *reciprocity-based* incentive mechanisms are excellent candidates to address such a scenario. Current approaches for this integrated video streaming, however, fail to produce acceptable results, since they either require symmetry of interest [2], reciprocation [1], [2], or are prone to false reports [4].

2 Related Work

The key aspect in an open P2P system is the presence of an effective and secure incentive mechanism to incentivize peers to share their resources, such as upstream bandwidth. Closed P2P systems, *e.g.* SopCast [5], do not need to provide incentives for peers to share, since protocol and source code are closed and protected by license agreements, which force users to share their processor and bandwidth.

In *reciprocity-based incentive mechanisms*, peers maintain histories of past transactions with other peers and use this information to decide to which peers to share their resources. These schemes can be based on direct reciprocity or indirect reciprocity. In *direct-reciprocity incentive mechanisms* such as Tit-for-tat (TFT) [2], a peer bases its decision solely on its own past experiences with other peers, rewarding peers which have contributed the most. TFT does not perform well in live video streaming, since the information is likely to flow in one direction only when a peer providing the stream is ahead of the peer receiving it, nor in VoD, since it requires that each peers be interested in something the other has. In *indirect-reciprocity incentive mechanisms*, the decision of a peer A about which a peer B to provide with resources also depends on the service that B has provided to other peers in the system. A transitive TFT mechanism can be used, typically using a shared history. CompactPSH [1] combines both approaches, TFT and transitive TFT, to exploit indirect reciprocity using both private and shared history, using MaxFlow to mitigate false reports. Although shown to be more effective than TFT in a P2P file-sharing scenario, CompactPSH has not yet been applied to P2P live or on-demand video streaming.

Report-based incentive mechanisms, such as Give-to-Get (GTG) [4], offer a transitive reputation score, letting peers favor uploading to other peers which have uploaded more to third peers. They do not expect reciprocity, which is a desirable property in both P2P live video streaming and VoD cases, where the information flows mostly in one direction. However, it relies on truthful reports from peers, a fact that

makes GTG not useful in real life. The missing property is providing guarantees offered by reciprocity-based mechanisms.

3 Proposed Approach

The approach investigated will comprise three incentive mechanisms: (a) an *indirect-reciprocity incentive mechanism*, which will be refined and applied to both live and on-demand P2P video streaming; (b) a *report-based incentive mechanism*, which extends the work in the area of being Sybil-resistant, based on random sampling and P2P auditing methods, and (c) a combination of the two, which will determine a balanced compromise between *reciprocity*- and *report-based* incentive mechanisms.

Indirect-reciprocity incentive mechanisms have properties, which address asymmetry of interest; the case when a peer provides stored content and is not interested in any content the requesting peer has to offer and when a user switches channels. It has been applied to P2P file-sharing systems [1], showing improvement in download times, while offering protection against false reports, which is inherent from *reciprocity-based incentive mechanisms*. The first step is to adapt CompactPSH [1]to a P2P video streaming scenario, creating a new incentive scheme VideoPSH. In file sharing, peers exchange chunks of files in any order, and a chunk will remain interesting to other peers for a long time. In P2P live streaming, the download rate has an upper bound dictated by the bitrate of the video stream, and a lower bound dictated by the loss tolerated by the video codec used, and chunks get obsolete as they lose their liveness. In VoD, chunks remain interesting for a longer time, and download rate may be faster than the bitrate of the video stream. The new approach will examine its effects on (1) QoE (Quality-of-Experience) metrics, (2) understanding and improving its scalability, (3) Sybil- and collusion-proofness properties in the given scenario.

A fundamental problem of *reciprocity-based incentive mechanisms* is that it is impossible for the peercaster to use them, since they do not download. Also, it is difficult to transfer reputations for more than one hop, due to information becoming outdated. Hence, a new *report-based incentive mechanism* (NRBIM) will be developed and evaluated. The mechanism is inspired by multi-level marketing schemes, such as AmWay. It will function on the base that each peer is given a score, which takes into consideration the recursive contribution of each peer to the entire P2P network; therefore, in order to increase their own score, peers need to upload to peers with high score. A higher score improves the chance of getting close to the peercaster, be more reliable, and experience shorter delay when watching at or near live streaming. Scores will be calculated using a Sybil-resistant system, which penalizes peers that are suspects of being Sybils. Finally, a distributed auditing system will verify peers claims for their score. Such an incentive mechanism is expected to produce good results with regard to scalability and fairness, while offering a proved resistance to malicious peers that lie about their or other peers contribution, collude, or create Sybils. The approach will investigate trade-offs between chance or frequency of the auditing and return achieved by malicious peers. The development of such an incentive mechanism does represent a new contribution to the area of *report-based incentive mechanisms*.

Finally, this approach proposes the investigation of the combination of both approaches to complement advantages and limitations of both. The main advantage of *reciprocity-based incentive mechanisms*, like VideoPSH, is that they use reciprocity to prevent overspending of resources and increase fairness. In the NRBIM proposed, peers may achieve partial success when cheating, but they will have a clear chance of getting caught as well, which will be a trade-off between the frequency of the sampling scheme used for auditing. If contributions can be verified partially by reciprocation, the success of cheating peers is expected to be lower.

Likewise, the possible disadvantage of VideoPSH concerning its limited view, since only reputation transfer of one hop is currently feasible in CompactPSH, can be overcome by using verifiable reports, as in NRBIM. Another difference between NRBIM and CompactPSH refers to the durability of the information. CompactPSH allows reputation information to be retained for later use, if it is assumed that peer identities are durable, while NRBIM uses only instant information to evaluate the contribution of peers. The use case studied will profit from reputation information that is durable, since peers must be incentivized to store and provide chunks to other peers and be reciprocated eventually. The resulting incentive mechanism will be resistant to Sybil attacks up to a proven point.

4 Summary

The development of incentive mechanisms suitable for an integrated live streaming and VoD scenario is challenging. Thus, this paper proposes three possible mechanisms tackling the fairness problem using different paradigms. While the first two incentive mechanisms will represent a contribution in their own, the third one is planned to complement their characteristics in an integrated approach.

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