Towards an Incentive Mechanism for Peer-to-Peer Multimedia Live Streaming Systems

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I. Introduction

Peer to peer (P2P) systems have demonstrated their ability to provide large scale content distribution in the Internet. This is clearly the case for file sharing P2P applications such as BitTorrent [1] or eDonkey [2]. In fact, work has moved on from file sharing to multimedia streaming of live content such as live TV over P2P networks (P2P IPTV). There are already numbers of P2P IPTV applications deployed on the Internet, inspired by the P2P architecture of BitTorrent [3] such as PPStream [4].

The P2P architecture of BitTorrent rests largely on the use of a mechanism to align incentives between peers in the system. The incentive mechanism is used to enforce collaboration and exchange of data between peers, so that fairness is respected in the P2P system. However, BitTorrent is originally designed for file sharing and is not adapted for live multimedia streaming. Multimedia flows impose temporal constraints which are not present for mere file distribution and result from the continuous nature of the transmission. Hence peers synchronize with the data each needs and cannot transmit data in return. Thus, fairness is not achieved in the P2P system.

In this extended abstract, we uncover the way that the incentive mechanisms in BitTorrent are not well suited to streaming live multimedia, and based on P2P systems that we have measured, we propose a new incentive mechanism designed for distribution of live multimedia streaming over a P2P network.

II. Architecture of BitTorrent

A. Review of BitTorrent Functionality

BitTorrent divides a file into a collection of blocks (*chunks*) to distribute it, and peers have to recover all the blocks to download a whole file. To achieve this, peers exchange with each other a *buffer map*, that is, information about which data blocks they own, and which they want to recover, organizing the P2P network in a transient mesh. To allow fairness between peers in the P2P system, an incentive mechanism is used to enforce collaboration and exchange of blocks of data. The incentive mechanism in BitTorrent rests on reciprocal exchange of data between peers (*tit for tat*). More precisely, a peer transmits a block to another peer if the either transmits one in return. Peers are thus encouraged to contribute to the peer-to-peer system since they are repaid by receiving new blocks.

Since all the blocks of a file must be downloaded before the file can be used, each block has equal importance, and peers need to recover blocks of a file in no particular order without regard for their position in the file (beginning, middle or end of file).

B. Limitations of BitTorrent's Incentive mechanism

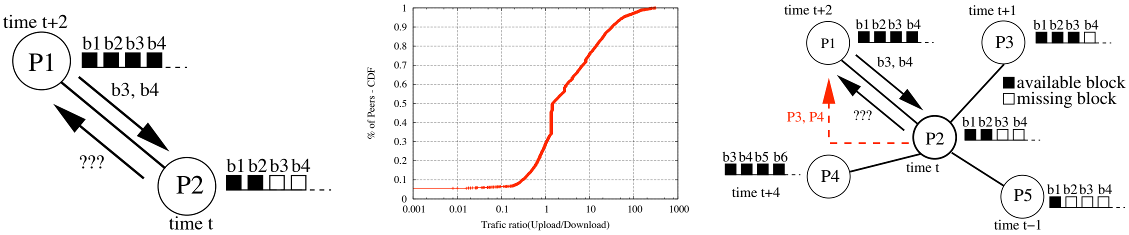
Differently from files, live multimedia streams are consumed on-the-fly as they are received. For a live multimedia stream, blocks do not have the same importance given their position in the flow, since blocks have to be consumed in real time (i.e. on-the-fly). Hence there exists a temporal constraint and results from the continuous nature of the transmission. In concrete terms, block b in a flow must be consumed before block b+1 from the same flow to respect the playback time of each block, and to render the flow with good quality.

If we study the scenario illustrated on Fig. 1(a) with a multimedia flow: each peer has different blocks and finds itself at a different point in the playout. Peer P1 is at playout point t+2, has received more blocks (b1 to b4) and is further ahead than peer P2 which is still at point t with only blocks b1 and b2. P1 hold blocks that are indeed of interest to peers P2. The opposite is not the case: blocks held by peers P2 (time t) are of no interest to P1 (time t+n), since it has already recovered those and is moving ahead.

P2 does not transmit data to P1, not because it is uncooperative, but because it is in the nature of the content and the temporal constraints that makes it pointless. Peers synchronize with the data each needs. If peers send data without reciprocation, fairness is not achieved. This is indeed what we observe in the course of our measurements of P2P IPTV systems.

C. Observations of Real Systems

We performed passive measurement of the traffic generated by PPStream, one of the most popular P2P IPTV applications [5]. Figure 1(b) shows the cumulative distribution function (CDF) of the relationship between traffic ratio (upload/download) between a peer which we control, and all the peers with which it exchanges data. The CDF indicates that 30% of peers are altruistic with our peer. The 70% of peers remaining are beneficiaries of our altruism. Overall, the system is never fair to us, with the large majority being mainly consumers (ratio>1) than producers (ratio<1).



(a) P2P live streaming

(b) Trafic ratio of PPStream

(c) New incentive mechanism for P2P live multimedia streaming

Fig. 1. (a) and (b): Limitations of BitTorrent-like P2P systems for Multimedia Live Streaming. (c): Proposed solution

These observations illustrate the need for an incentive mechanism which allows all the peers truly to collaborate in the network, even if the continuous nature of the content being distributed mitigates against the transmission of data in a reciprocating manner.

III. Towards a novel incentive mechanism

We propose a new incentive mechanism to P2P live multimedia streaming systems which introduces a new criterion for evaluation of the collaboration of a peer. This criterion will allow us to show whether a consuming peer invests in the exchange or not.

In our mechanism, consumer peers advertise new peers capable to offer data to provider peers. This allows providers peers to discover new sources of data. Thus if a peer transmits no data itself to one of its provider peers, it proves it is collaborating and it is indirectly allowed to receive data. This new type of collaboration encourages peers constantly to find new peers and propose them to its data providers.

Figure 1(c) illustrates the new incentive mechanism we propose. Peers P1 and P2 are in the same configuration as before (Fig. 1(a)). Remember that BitTorrent creates a mesh between the peers which own various blocks of data. In our example, P2 knows P1, P3 and P4. They are ahead the playout time of P2 so they have blocks which are interesting for P2. P2 provides also P5, which is behind (at time t-1). P1, P3, P4 and P5 constitute the neighborhood of P2.

Since P1, P3 and P4 are situated ahead the playout point of P2, it is highly likely that P1, P3 and P4 are situated at close playout points and are looking for common blocks of data. Because P1, P3 and P4 have their own neighborhood with different content provider peers, these three peers also hold blocks possibly interesting to others. This is the case for P4 that has interesting blocks for P1 (b5, b6). Thus, peers P1, P3 and P4 are certainly interested to establish peering relationship together to exchange blocks of data, but they still do not know each other.

Even though the continuous nature of the media means that P2 is not able to offer data to P1 in return (black arrows in Figure 1(c)), P2 can collaborate in the system by transmitting to P1, information about the new potential sources of data (red-dashed arrow in Figure 1(c)). P2 is incentivized to find these new pairs and report them to providers.

In our example, P2 inform either P3, P4 or even P5 (or both) about P1. The reaction of P1 according to the new discovered peers is as follows:

- P4 holds blocks which interest P1. P1 and P4 have to organize themselves to exchange blocks of data. However, P2 proposed a new source of data to P1, proving its fair collaboration. P1 must grant P2 in return by continuing to send data to P2. P1 may also increase the amount of data it sends to P2 to show its gratitude.
- P3 does not hold blocks which interest P1 but P1 can deduce, with the *buffer map*, that P3 is a provider to P2. Even though the information does not let P1 discover a new source of data, P2 collaborates actively and deserves to continue to receive data from P1. P1 can also limit the delivery of data towards P2, notably if the resources of P1 are used by many peers.
- If the announced peers (P3 or P4) are already known by P1, P1 will have the same reaction as the previous case. P2 collaborates actively and P1 continues to send it data. However, the information was not relevant for P1, which can limit the amount of data it sends to P2.
- If P2 informs P1 about P5; P5 has no block of interest for P1, and is in addition, behind P2, P1 estimates P2 has not made enough effort to find new peers. P1 can then sanction P2 by decreasing the amount of data it sends to P2 or by canceling their peering relationship.

IV. Future Work

Evaluating this kind of mechanism is very challenging. Some do it by implementing the mechanism directly into an open client, while others prefer simulations for trackable large-scale behavior. We are currently implementing this mechanism in a commonly used simulator (PeerSim [6]) to have a fair validation of the proposed mechanism.

References

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