Contracts: Practical Contribution Incentives for P2P Live Streaming

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Live streaming with PPLive

- **P2P** distribution
- **Over 20 million active users** worldwide
- **Current design offers no reward for capacity contributions**

How to provide contribution incentives?
Overview

1. Challenges for *live streaming incentives*

2. *Contracts* design

3. Evaluating *PPLive with Contracts*
PPLive design
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Wire-level protocol very similar to BitTorrent
Can we apply tit-for-tat?

- *Bilateral reciprocation:* Contribute to peers that contributed to you

- *Challenges* for live streaming:
  - Capacity *heterogeneity*
  - Limited *trading opportunities*
  - No *compelling reward*
Capacity heterogeneity

- Top 10% of users contribute 58% of total capacity
Capacity heterogeneity

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Capacity utilization

All users watching at max possible quality

Supported users
Capacity heterogeneity

• Top 10% of users contribute 58% of total capacity

• With balanced exchange:
  - Maximizing quality excludes 86% of users
  - Supporting 95% of clients wastes 85% of capacity
Imbalanced exchange?

- Is *relaxing balance* sufficient?
- Reciprocation depends on *trading opportunities*

- But, live streams *swarm over few blocks*
  - Clients near the source: *block monopoly*
  - Distant clients: *perpetual trade imbalance*

- Outcome: *few trading opportunities*
Transfer opportunities

Data availability from a snapshot of client buffer states
Transfer opportunities

Reciprocation most common with similar distance to the source

Data availability from a snapshot of client buffer states
Transfer opportunities

Most transfers are between peers with a large imbalance of blocks to send.

Data availability from a snapshot of client buffer states
Rewarding contribution

- For bulk data: 
  *Increase contribution rate* $\rightarrow$ *increase download rate*

- Live streaming: *inelastic*
  All users download at the stream rate

How to create a compelling reward?
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Contracts design overview

Global evaluation contract rather than bilateral reciprocation

- Recognizes *globally effective contributions*

Reward contributions with robustness by optimizing the overlay topology

- If the system becomes capacity constrained, *contributors fail last*
Evaluating contributions

• Goals:

 1. **Contribute capacity**
     - As in any P2P system, contributions required

 2. **Choose effective peers**
     - Live streaming has playback deadlines
     - Prioritize peers that replicate data quickly
Tracking contributions

- *Cryptographic receipts* attest to the contributions of peers
- Presented to other peers to *demonstrate contributions*
Tracking contributions

• Cryptographic receipts attest to the contributions of peers

• Presented to other peers to demonstrate contributions
  (From 1 to E, for example)
Tracking effectiveness

- **Gossip receipts** in a one hop neighborhood
- Allows E to compute:
  - **Effectiveness** of peers (1)
  - **Contributions** of peers of peers (2)
- Clients prioritize effective peers
Evolving the topology

• Compute contributions of distant peers using forwarded receipts

• Preferentially connect to highest capacity peers
  Prune unproductive peers

• High capacity peers: percolate towards the source
• Low capacity peers: pushed to mesh periphery
Evolving the topology

- **Compute contributions** of distant peers using forwarded receipts

Because failures cascade, proximity to the source improves quality of service

- **High capacity peers**: percolate towards the source
- **Low capacity peers**: pushed to mesh periphery
Collusion defenses

• Limit identity creation at PPLive coordinator

• Weight contributions by diversity of network addresses

• Flow integrity check —
  Incoming data rate cannot exceed stream rate
  Outgoing data rate cannot exceed capacity
Overview

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3. Evaluating *PPLive with Contracts*
Evaluation overview

This talk

- Contracts improves performance
- Contracts strengthens contribution incentives

Paper

- Computational and network overhead
- Comparison with FlightPath [OSDI’08]
- Topology convergence
- Over-provisioning and loss-rate
Experimental setup

- Modified PPLive to support *Contracts* and rate-based *tit-for-tat*
- Synthetic broadcast on *100 Emulab machines*
- *Churn* from clients joining at 10 second intervals, remaining for 20 minutes, repeating for 2 hours
- *Capacities* from measured distribution of over 90,000 PPLive users
PPLive performance

Stream rate chosen to induce capacity constraints
PPLive performance

Stream rate chosen to induce capacity constraints

28% of peers receive 90% of blocks by the deadline
PPLive performance

Stream rate chosen to induce capacity constraints
PPLive + tit-for-tat

Tit-for-tat reduces performance for live streaming
PPLive + tit-for-tat

Tit-for-tat reduces performance for live streaming
PPLive + Contracts

Contracts substantially improves performance
PPLive + Contracts

Contracts substantially improves performance

Loss-free playback
4× unmodified PPLive

Rate-based tit-for-tat
Unmodified PPLive
PPLive with Contracts

Cumulative fraction of peers

Fraction of blocks received by deadline
Incentives

Contracts strengthens contribution incentives
I ncentives

Tit-for-tat reward increases slowly, varies widely
Incentives

Contracts strengthens contribution incentives
Conclusions

• Live streaming exhibits *new challenges* for fostering P2P contribution incentives

• Contracts improves *performance* and *incentives*

• *Evaluation contract* rather than bilateral exchange

• Restructure topology to *reward contributions with quality of service*