CONTRACTS: PRACTICAL CONTRIBUTION INCENTIVES FOR P2P LIVE STREAMING
An Overview by Alex Loeb
DISTRIBUTING LIVE CONTENT

- Why it’s different
- What’s been done
- What’s wrong with what’s been done
- What Contracts improves
- How well Contracts’ improvements work
WHY LIVE CONTENT IS DIFFERENT

- Not all of the content is available immediately
- All available content expires eventually
- Heterogeneous capacities become significant
WHAT’S BEEN DONE

- In the beginning … there was IP Multicast … sort of
- Approximate Multicast with a Tree Overlay
  - Narada, Overcast, Yoid
    - SplitStream later improves leaf node utilization
- Mesh-based Overlay Network (P2P)
  - Coolstreaming/DONet
- P2P-VoD, streaming, but not live
  - PPLive
- P2P Incentives
  - Bilateral exchange, multilateral exchange
- Live Streaming P2P Incentives
  - Many and diverse...
LIVE STREAMING INCENTIVES

- Tit-for-Tat
  - Common (non-streaming) P2P mechanism
- Rank order-based incentive through Service Differentiation
  - Rank all peers based on contributions (tournament)
- Use Multiple Trees (differentiated services)
  - Only subscribe to subset of trees based on sharing
- BAR Gossip (and later FlightPath)
  - Tit-for-Tat with a twist
  - Exchange data, but require a final key exchange to make the data useful
HONORABLE MENTION

- Fair File Swarming with FOX
  - Not concerned with Streaming at all, but…
  - Uses Mutually Assured Destruction to achieve provably optimal performance in the presence of selfish nodes
Live Streaming Incentives (Problems)

- Tit-for-Tat (Bilateral exchange)
  - More on this later…
- Rank order-based incentive through Service Differentiation
  - Low capacity nodes get hurt
- Use Multiple Trees (differentiated services)
  - Requires all nodes to play fair
- BAR Gossip (and later FlightPath)
  - See Tit-for-Tat above…
WHAT CONTRACTS IMPROVES

- Builds on PPLive
- Shows Bilateral Exchange performs poorly
- Reward Global Contributions
  - Strengthen incentives
  - Improve performance
PPLive Overview

- P2P Live/On-Demand Streaming
  - Seed Servers hosting content
  - Trackers coordinating users watching same content
- All peers maintain a large set of directly connected peers
- Seed Servers are a last resort source
- Peers do not prioritize other peers
  - High and Low contributors treated as equals
  - Swarming with bilateral exchange
PROBLEMS WITH BILATERAL EXCHANGE IN PPLive

- Heterogeneous Capacity among nodes
  - Study shows top 10% of nodes provide 58% of total capacity in PPLive
  - Tit-for-Tat
    - Either everyone transfers at the lowest nodes capacity
    - Or all the nodes who can’t keep up get left out

- Limited Bandwidth Needs
  - No reason for high capacity nodes to over take production rate

- Data Blocks are not all equal
  - In Live Streaming, blocks expire quickly
  - Reduction in mutually beneficial trade opportunities
Delay Sensitivity

- **Theorem 2** Any topology in which a peer $i$ has lower bandwidth than peer $j$ but $i$ has more descendants than $j$ has higher average block delay than the topology obtained by swapping $i$ and $j$ if one of the following two conditions hold: (a) the topology is a balanced tree, or (b) $i$ is an ancestor of $j$.

![Diagram](image)

Figure 2: Illustration for Theorem 2: Node $j$ has higher upload capacity than node $i$ but has fewer descendants.
BILATERAL EXCHANGE AND LIVE STREAMING

- What Theorem 2 means...
  - Higher capacity nodes should be closer to the source (to reduce delay)
  - …but then Higher capacity nodes get newer blocks first (before lower capacity blocks)
  - …but then Higher capacity nodes don’t benefit from lower capacity nodes
  - …but all nodes evaluated by their utility (using Bilateral Exchange)
  - …so Bilateral Exchange is bad for delay (because low capacity nodes have to be closer to the source)
ALIGNING INCENTIVES AND PERFORMANCE

- Put high capacity nodes close to the source
  - Optimizes distribution topology to reduce delay and maximize utilization
  - They get better quality playback

![Graph showing percentage of missed blocks vs. average distance from broadcast source.](image)

**Figure 4:** The fraction of blocks missing playback deadlines as a function of distance from the broadcast source. Playback quality is best for clients nearest to the source.
THE PRINCIPAL-AGENT PROBLEM


Key to Contracts is “role asymmetry”

CONTRACTS

“Provider provides service proportional to one’s ability to replicate the data further”

Provide Global Topology Optimization
- Use a universal Contract to cause high capacity nodes to move closer the source
- Track global information to facilitate this
CONTRACTS TOPOLOGY

Source
Tracker

Live Feed

Node
Sub-tree
Sub-tree

Receipt Digests
Hey! I'm Contributing ... Really, I Swear!

- Centralized Verification by the Tracker
  - Each node keeps receipts of all transactions
  - Each node sends receipt digest to Tracker periodically
  - Receipts and Digests signed for validity

- Central Track must reassemble receipts and compute node contributions

- Central Tracker then sends the node a new list of peers which determine that node’s place in the topology
**CONTRACTS EVALUATION**

![Graph showing performance comparison]

**Figure 8:** Performance comparison of unmodified FlightPath, PPLive, rate-based tit-for-tat, and *Contracts*. 
Figure 9: Delivery rate as a function of contribution
Figure 10: The size of receipt digest messages as a function of the digest update interval.
THANKS!