Incentive Mechanisms for QoS on P2P Systems

Raúl Leonardo Landa Gamiochipi

Department of Electronic and Electrical Engineering
University College London
What is PeerLive?

• Goal:
  – Near **real-time video** distribution using P2P technology

• Techniques:
  – QoS Overlays
  – Synthetic coordinate systems
  – Market-driven resource allocation
  – Reputation systems
Why Incentive Mechanisms?

PeerLive

QoS

User-level Incentives

Peer-level Incentives
What must peers do?

- The PeerLive incentive mechanism should help peers decide:
  - Which fragment requests to answer
  - In which order to answer them
  - How to measure peer contributions (QoS-aware)
  - How to reciprocate previous interaction (QoS-aware)
State of the Art: Incentives for QoS

• Contribution-based peer selection
  – Peer contribution ranking (Chuang, Habib 2006)
  – Creating downloader coalitions (Epema, Iosup et. al. 2007)

• Reciprocity for queue management
  – Using trust scores as queue priorities (Grothoff, 2003)
  – Token Stealing Algorithm (Pai, Mohr 2006)
Why Market-based incentives?

- Complex QoS conditions
  - Strategic, heterogeneous users
  - Changing network conditions

- Completely distributed

- Catallaxy (Friedrich Hayek, The Use of Knowledge in Society - 1945)
PeerLive: A Network of Local Markets

• Peer neighbourhoods are *local markets*
  – Every node “buys” and “sells” bandwidth to its neighbours
  – Prices balance supply and demand (Kearns et. al. 2004)

• Peers pay currency for the transmission of fragments
PeerLive: A Network of Local Markets

- The “wealth” of a peer is stored in accounts on all its trading partners
PeerLive: A Network of Local Markets

- The “wealth” of a peer is stored in accounts on all its trading partners

Peer 2 sold peer 1 a fragment for a cost $p_2$

Peer 1 pays by increasing the account of peer 1 by $p_2$
Making Bandwidth a Commodity

- Peers have a Shared token bucket to control outgoing bandwidth
  - Tokens represent a given number of bytes
  - Tokens are added periodically, according to peer capacity, and consumed when fragments are sent
Making Bandwidth a Commodity

- Additionally, peers have *Private token buckets* for each one of the peers they trade with
  - Tokens can be bought. This transfers them from the Shared bucket to the Private Buckets.
  - This is equivalent to reserving bandwidth.

<table>
<thead>
<tr>
<th>Accounts</th>
<th>Sent Fragments</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n_3$</td>
<td>$n_1$</td>
</tr>
<tr>
<td>$n_2$</td>
<td>$p_2$</td>
</tr>
<tr>
<td>$n_3$</td>
<td>0</td>
</tr>
</tbody>
</table>
Making Bandwidth a Commodity

- Additionally, peers have *Private token buckets* for each one of the peers they trade with
  - Tokens can be bought. This transfers them from the Shared bucket to the Private Buckets.
  - This is equivalent to reserving bandwidth.

<table>
<thead>
<tr>
<th>Accounts</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$n_2$</td>
<td>0</td>
</tr>
<tr>
<td>$n_3$</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sent Fragments</th>
<th></th>
</tr>
</thead>
</table>
PeerLive: Token Stealing Algorithm with Price Mapping

- When requests arrive from peers with active accounts:
  1. They are ordered on decreasing account balance order

\[ p_i : \text{Currency offered for fragment} \]

\[ l_i : \text{Fragment size (token units)} \]

<table>
<thead>
<tr>
<th>Accounts</th>
<th>( n_2 )</th>
<th>( p_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n_3 )</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

\[ n_2 \rightarrow (p_1, l_1) \]
\[ n_2 \rightarrow (p_2, l_2) \]
\[ n_3 \rightarrow (p_3, l_3) \]
\[ n_3 \rightarrow (p_4, l_4) \]
PeerLive: Token Stealing Algorithm with Price Mapping

- When requests arrive from peers with active accounts:
  1. They are ordered on decreasing account balance order

\[ p_i : \text{Currency offered for fragment} \]

\[ l_i : \text{Fragment size (token units)} \]

<table>
<thead>
<tr>
<th>Accounts</th>
<th>( n_2 )</th>
<th>( n_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p_2 )</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
PeerLive: Token Stealing Algorithm with Price Mapping

- When requests arrive from peers with active accounts:
  1. They are ordered on decreasing account balance order

<table>
<thead>
<tr>
<th>Accounts</th>
<th>$n_2$</th>
<th>$p_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n_3$</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Diagram:
- $n_1$ (peers)
- $n_2$ and $n_3$ (accounts)
- $p_2$ (price mapping)
PeerLive: Token Stealing Algorithm with Price Mapping

- When requests arrive from peers with active accounts:
  1. They are ordered on decreasing account balance order
  2. Their currency is used to buy tokens
PeerLive: Token Stealing Algorithm with Price Mapping

- When requests arrive from peers with active accounts:
  1. They are ordered on decreasing account balance order
  2. Their currency is used to buy tokens
  3. If the tokens are enough to send the request, it is serviced (tokens are consumed).

<table>
<thead>
<tr>
<th>Accounts</th>
<th>$n_2$</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$n_3$</td>
<td>0</td>
</tr>
</tbody>
</table>

Sent Fragments
PeerLive: Token Stealing Algorithm with Price Mapping

- When requests arrive from peers with active accounts:
  1. They are ordered on decreasing account balance order
  2. Their currency is used to buy tokens
  3. If the tokens are enough to send the request, it is serviced (tokens are consumed).
  4. Non-consumed tokens are sold back to the shared bucket.
PeerLive: Token Stealing Algorithm with Price Mapping

- Peers now compete with each other for the tokens left on the shared bucket
  1. Their benefit per token unit ($t_i$) is calculated

\[
t_2 = \frac{p_2}{l_2}
\]

\[
t_3 = \frac{p_3}{l_3}
\]

\[
t_4 = \frac{p_4}{l_4}
\]
PeerLive: Token Stealing Algorithm with Price Mapping

- Peers now compete with each other for the tokens left on the shared bucket

1. Their benefit per token unit is calculated
2. They are ordered in decreasing order of benefit

\[ t_2 > t_3 > t_4 \]

<table>
<thead>
<tr>
<th>Accounts</th>
<th>$\epsilon$</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n_2$</td>
<td>$\epsilon$</td>
<td>0</td>
</tr>
<tr>
<td>$n_3$</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
PeerLive: Token Stealing Algorithm with Price Mapping

- Peers now compete with each other for the tokens left on the shared bucket

  1. Their benefit per token unit is calculated
  2. They are ordered in decreasing order of benefit
  3. The requests are served until no tokens remain in the shared bucket

<table>
<thead>
<tr>
<th>Accounts</th>
<th>$n_2$</th>
<th>$n_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n_2$</td>
<td>$\epsilon$</td>
<td></td>
</tr>
<tr>
<td>$n_3$</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
PeerLive: Token Stealing Algorithm with Price Mapping

- Peers now compete with each other for the tokens left on the shared bucket
  1. Their benefit per token unit is calculated
  2. They are ordered in decreasing order of benefit
  3. The requests are served until no tokens remain in the shared bucket

<table>
<thead>
<tr>
<th>Accounts</th>
<th>$n_2$</th>
<th>$n_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\epsilon$</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
PeerLive: Token Stealing Algorithm with Price Mapping

• Peers now compete with each other for the tokens left on the shared bucket
  1. Their benefit per token unit is calculated
  2. They are ordered in decreasing order of benefit
  3. The requests are served until no tokens remain in the shared bucket
PeerLive: Token Stealing Algorithm with Price Mapping

- Peers now compete with each other for the tokens left on the shared bucket
  1. Their benefit per token unit is calculated
  2. They are ordered in decreasing order of benefit
  3. The requests are served until no tokens remain in the shared bucket
  4. Non-consumed tokens are left in the shared bucket for the next round.

<table>
<thead>
<tr>
<th>Accounts</th>
<th>$n_2$</th>
<th>$\epsilon$</th>
<th>$n_3$</th>
<th>0</th>
</tr>
</thead>
</table>

| Sent Fragments | $n_1$ | $\rightarrow$ | $n_2$ | $n_3$ | |
PeerLive: Summary

- Bandwidth contributions build up peer accounts
- This accumulated wealth is used to get priority access for peer service
- Price reflects fragment value, including QoS
- Support for strategic peers
PeerLive: Future Work

- Supply-demand matching protocol
- Market convergence optimality
- Reputation system
- Currency circulation
Thank You!

• www.peerlive.org

• Any questions?