Resource Allocation in Underprovisioned Multioverlay Live Video Sharing Services

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Massively Multiplayer Online Game collaborative tool
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Players emit user-generated videos

Developed by the CNG (Community Network Game) project

Integrated in "The Missing Ink" (www.missing-ink.com)
Xfire: online game player video casting platform
Challenges

- Thousands of simultaneous video sources
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- Each video is seen by a dozen of players

Solution: multioverlay P2P video streaming system
Challenges

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- Each video is seen by a dozen of players
- Video sources are low-capacity computers

→ peer-to-peer may be useful

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CDN is not cost-effective
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CDN is not cost-effective
   \[ \rightarrow \text{peer-to-peer may be useful} \]

Solution: multioverlay P2P video streaming system
1. Multioverlay P2P video streaming system

2. Inter-overlay bandwidth allocation problem

3. Performance evaluation

4. Conclusion
A player can simultaneously watch several videos.
System design points

Intra-overlay P2P video streaming:

- Mesh-based: bandwidth fluctuation and peer dynamics
System design points

Intra-overlay P2P video streaming:
- Mesh-based: bandwidth fluctuation and peer dynamics

Inter-overlay bandwidth allocation:
- Peers allocate their uplink bandwidth
- Independent with intra-overlay video streaming
Avancement

1. Multioverlay P2P video streaming system
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Peers watching several videos should share their uplink

Problem: How to allocate bandwidth to overlays?
Bandwidth Allocation Problem

Peers watching several videos should share their uplink

Problem: How to allocate bandwidth to overlays?

overlay_1  overlay_2  overlay_3

p_1  p_2  p_3  p_4
uplink: 9  uplink: 5  uplink: 8  uplink: 8
Peers watching several videos should share their uplink.

Problem: How to allocate bandwidth to overlays?

```
overlay₁

| P₁  | uplink: 9 |
.overlay₂

| P₂  | uplink: 5 |
.overlay₃

| P₃  | uplink: 8 |
| P₄  | uplink: 8 |

peer subscribes to overlay
```
Peers watching several videos should share their uplink.

**Problem:** How to allocate bandwidth to overlays?
Bandwidth Allocation Problem

Peers watching several videos should share their uplink capacity.

Problem: How to allocate bandwidth to overlays?

overlay\_1 \rightarrow \text{overlay\_2} \rightarrow \text{overlay\_3}

\begin{align*}
\text{overlay\_1} & : \text{demand} = 18, \text{capacity} = 12 \\
\text{overlay\_2} & : \text{demand} = 12, \text{capacity} = 7 \\
\text{overlay\_3} & : \text{demand} = 18, \text{capacity} = 8 \\
\end{align*}

\begin{align*}
p\_1 & : \text{uplink} = 9 \\
p\_2 & : \text{uplink} = 5 \\
p\_3 & : \text{uplink} = 8 \\
p\_4 & : \text{uplink} = 8 \\
\end{align*}

---6--- peer allocates to overlay
Peers watching several videos should share their uplink.

Problem: How to allocate bandwidth to overlays?

**overlay\(_1\)**
- Peer 1: uplink: 9, capacity: 12, demand: 18
- Peer 2: uplink: 5, capacity: 7, demand: 12

**overlay\(_2\)**
- Peer 3: uplink: 8, capacity: 22, demand: 18

**overlay\(_3\)**
Objective 1: minimizing the waste of resources

Overlay provisioning:

- overlay capacity - overlay demand
  - overlay capacity - overlay demand $\geq 0$: overprovisioned overlay ($G^+$)
  - overlay capacity - overlay demand $< 0$: underprovisioned overlay ($G^-$)
Objective 1: minimizing the waste of resources

Overlay provisioning:

- Overlay capacity - overlay demand
  - Overlay capacity - overlay demand $\geq 0$:
    - Overprovisioned overlay ($G^+$)
  - Overlay capacity - overlay demand $< 0$:
    - Underprovisioned overlay ($G^-$)

Objective: minimizing total underprovisioning

$$\sum_{\text{overlay} \in G^-} |\text{capacity} - \text{demand}|$$
Our solution: a max-flow

Node \( S_1 \):
- Demand: 18
- Capacity: 6

Node \( S_2 \):
- Demand: 12
- Capacity: 4

Node \( S_3 \):
- Demand: 18
- Capacity: 8

Node \( p_1 \):
- Uplink: 9

Node \( p_2 \):
- Uplink: 5

Node \( p_3 \):
- Uplink: 8

Node \( p_4 \):
- Uplink: 8
Our solution: a max-flow
Our solution: a max-flow

\[
\begin{align*}
\text{source} & \quad \text{sink} \\
q & \\
0/12 & 0/8 & 0/10 \\

s_1 & \quad s_2 & \quad s_3 \\
p_1 & \quad p_2 & \quad p_3 & \quad p_4 \\
0/9 & 0/5 & 0/8 & 0/8 \\
f & \\
\end{align*}
\]
Our solution: a max-flow
Objective 2: for underprovisioned system

Underprovisioned system:

\[ \sum_p \text{bandwidth} < \sum_{\text{overlay}} \text{required bandwidth} \]
Objective 2: for underprovisioned system

Underprovisioned system:

\[ \sum_p \text{bandwidth} < \sum_{\text{overlay}} \text{required bandwidth} \]

Given objective 1, how to share the resource deficit?
Objective 2: for underprovisioned system

Underprovisioned system:

\[ \sum_{p} \text{bandwidth} < \sum_{\text{overlay}} \text{required bandwidth} \]

Given objective 1, how to share the resource deficit?

- popularity: the most popular sources first
Objective 2: for underprovisioned system

Underprovisioned system:

\[ \sum_p \text{bandwidth} \ < \ \sum_{\text{overlay}} \text{required bandwidth} \]

Given objective 1, how to share the resource deficit?

- **popularity**: the most popular sources first
- **diversity**: the largest number of sources
Objective 2: for underprovisioned system

Underprovisioned system:
\[ \sum_p \text{ bandwidth} < \sum_{\text{overlay}} \text{ required bandwidth} \]

Given objective 1, how to share the resource deficit?

- **popularity**: the most popular sources first
- **diversity**: the largest number of sources
- **others**: e.g. **payment**: the premium sources first
Our solution: a min-cost max-flow
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add a cost function

popularity: \( \frac{1}{n}, \forall s \)
Our solution: a min-cost max-flow

1. Add a cost function:
   - **popularity**: $\frac{1}{n}, \forall s$
   - **diversity**: $1 - \frac{1}{n}, \forall s$

2. Graph representation:
   - **Nodes**: $s_1, s_2, s_3, p_1, p_2, p_3, p_4$
   - **Edges and Costs**:
     - $s_1$ to $s_2$: 0/12
     - $s_1$ to $s_3$: 0/8
     - $s_2$ to $s_3$: 0/10
     - $p_1$ to $p_2$: 0/9
     - $p_1$ to $p_3$: 0/5
     - $p_1$ to $p_4$: 0/8
     - $p_2$ to $p_3$: 0/8
     - $p_2$ to $p_4$: 0/8
     - $p_3$ to $f$: 0/8
     - $p_4$ to $f$: 0/8

3. Objective Function: Minimize the total cost of the flow.
Our solution: a min-cost max-flow

- **popularity**: \( \frac{1}{n}, \forall s \)
- **diversity**: \( 1 - \frac{1}{n}, \forall s \)
- **payment**: \[
\begin{cases}
1, & \text{if } s \text{ is premium} \\
2, & \text{otherwise}
\end{cases}
\]
Avancement

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System practicability

- **Peer dynamics**
  - Peers periodically report their estimated upload bandwidth
  - Server periodically recomputes, and sends bandwidth allocation

- **Light peer server communication overhead**
  - **0.8 Mbps** server upload bandwidth: 100,000 peers, 1min period, 3 average watching overlays × 2 bytes
  - **0.8 Mbps** server download bandwidth: 100,000 peers, 1min period, 4 bytes bandwidth and 4 bytes peer ID.

- **Min-cost-max-flow algorithm computation time**

<table>
<thead>
<tr>
<th>nb. peers</th>
<th>1,000</th>
<th>5,000</th>
<th>10,000</th>
<th>50,000</th>
<th>100,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>time (sec)</td>
<td>0.005</td>
<td>0.086</td>
<td>0.311</td>
<td>7.455</td>
<td>31.887</td>
</tr>
</tbody>
</table>
Realistic player upload bandwidth:
- log-normal distribution from 256kbps to 5Mbps
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Real trace based MMOG player relationship:
- Xfire \( \sim \) facebook network of *Smith College*
- Pareto’80-20: 80% videos from 20% most active players
Simulations : models and settings

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Watchers’ behavior leads to a Zipf video popularity :
- most popular : 330 peers; median popularity : 7 peers
Results - PSNR

CDF of peers

PSNR (dB)

1
0.8
0.6
0.4
0.2
0
naive

Multioverlay Bandwidth Allocation
Results - PSNR

CDF of peers

PSNR (dB)

naive
DAC
Results - PSNR

![CDF of peers](image)

- **naive**
- **DAC**
- **diversity-based**
- **popularity-based**

PSNR (dB) vs CDF of peers
Avancement

1. Multioverlay P2P video streaming system
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Conclusion

- A multioverlay P2P live video streaming system

- Inter-overlay bandwidth allocation problem
  - Minimizing global underprovisioning
  - Sharing the resource deficit with different policies
Thanks!