Magellan: Charting Large-Scale Peer-to-Peer Live Streaming Topologies

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Commercial P2P live streaming systems
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Coolstreaming, PPLive, PPStream, TVAnts, etc.
Peer-to-Peer Live Streaming — A Reality

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Hundreds of live channels with legal media content
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Common designs
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BitTorrent-like block exchange
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Simple peer selection with central tracking servers
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Common designs

BitTorrent-like block exchange
Simple peer selection with central tracking servers
mesh topologies are important for success
Related Work
Related Work

Topology characterization for P2P file sharing applications

KaZaA: Gummadi et al. [SOSP’03]
Old Gnutella: Jovanovic et al. [TELFOR’01]
New Gnutella: Stutzbach et al. [IMC’05]
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Measurement studies for P2P streaming applications

PPLive: Hei et al. [TOM’07]
TVAnts: Silverson et al. [NOSSDAV’07]
SOPCast: Ali et al. [WRAIPS’06]
Our Contribution
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Topology characterization of a realistic P2P live streaming system
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how the topology behaves at specific times
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how the topology behaves at specific times
how the topology evolves over time
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Established on
Our Contribution

Topology characterization of a realistic P2P live streaming system

- how the topology behaves at specific times
- how the topology evolves over time

Established on

120GB worth of traces from UUSee Inc., for Sep.-Oct. 2006
UUSee

One of the leading P2P streaming solution providers in China
UUSee

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800 channels, 400 Kbps streaming rate
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Unique peer selection algorithms
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Playback buffer count: main quality metric
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Mutual “good seed” recommendation
UUSee P2P Live Streaming

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Playback buffer count: main quality metric
Mutual “good seed” recommendation
Peer volunteering at tracking servers
Detailed measurements within UUSee client software

channel being viewed, buffermap
instantaneous aggregate receiving and sending throughput
individual P2P link throughput from/to all partners
Trace Collection

Detailed measurements within UUSee client software

channel being viewed, buffermap
instantaneous aggregate receiving and sending throughput
individual P2P link throughput from/to all partners

A standalone trace server

first report sent 20 minutes after peer join
subsequent reports sent every 10 minutes
Four questions
First Question:
First Question:

Does such a mesh-based P2P streaming application scale well in large-flash crowd scenarios?
Peer number statistics

![Graph showing peer number statistics over time](image)

- **Total peers**
- **Stable peers**

**Date (midnight)**

**Number of simultaneous peers**

$2.5 \times 10^5$
Peer number statistics

- 100,000 concurrent peers at any time
Peer number statistics

- 100,000 concurrent peers at any time
- 1 million different IP addresses per day

![Peer number statistics graph](image)
Peer number statistics

- 100,000 concurrent peers at any time
- 1 million different IP addresses per day
- Two daily peaks
- 100,000 concurrent peers at any time
- 1 million different IP addresses per day
- Two daily peaks
- One flash crowd scenario: 9pm, Oct. 6, 2006
Streaming quality

![Graph showing streaming quality over time for CCTV1 and CCTV4.]
Streaming quality

- Percentage of peers whose aggregate receiving throughput is higher than 90% of the streaming rate
Streaming quality

- Percentage of peers whose aggregate receiving throughput is higher than 90% of the streaming rate
- 75% peers have satisfying streaming rates
- Percentage of peers whose aggregate receiving throughput is higher than 90% of the streaming rate
- 75% peers have satisfying streaming rates
- Flash crowd streaming rate guaranteed

Streaming quality
Streaming quality

- Percentage of peers whose aggregate receiving throughput is higher than 90% of the streaming rate
- 75% peers have satisfying streaming rates
- Flash crowd streaming rate guaranteed
- Scalability established
Second Question:
Second Question:

Do peer degrees follow a power-law distribution?
Distribution of total number of partners
Distribution of total number of partners

– Not power-law nor two-segment power-law
Distribution of total number of partners

- Not power-law nor two-segment power-law
- Spike at larger degrees in the evenings than in the mornings
Distribution of total number of partners

- Not power-law nor two-segment power-law
- Spike at larger degrees in the evenings than in the mornings
- Spike at 25 during flash crowd scenario
Degree evolution

![Graph showing degree evolution over time with lines representing number of partners, indegree, and outdegree.](image)

- **Number of partner**
- **Indegree**
- **Outdegree**

**Average peer degree**

**Date (midnight)**

Sun Mon Tue Wed Thu Fri Sat Sun Mon Tue Wed Thu Fri Sat
Degree evolution

– Total number of partners peaks at peak hours
Degree evolution

– Total number of partners peaks at peak hours

– Active indegree consistently around 10
Degree evolution

- Total number of partners peaks at peak hours
- Active indegree consistently around 10

-> Each peer knows a lot of other peers, but not necessarily streams from many
Degree evolution

- Total number of partners peaks at peak hours
- Active indegree consistently around 10
  -> Each peer knows a lot of other peers, but not necessarily streams from many
  -> Scalability
Third Question:
Third Question:

Does there exist any clustering in the network?
From the degree perspective
From the degree perspective

– Examine the percentage of indegree/outdegree from peers in the same ISP
From the degree perspective

- Examine the percentage of indegree/outdegree from peers in the same ISP
- Majority of neighbors within the same ISP
From the degree perspective

- Examine the percentage of indegree/outdegree from peers in the same ISP
- Majority of neighbors within the same ISP
- Nature clustering of peers inside each ISP
Using small-world metric

**Clustering coefficient**

$$C_g = \frac{1}{n} \sum_{i=1}^{n} C_i$$

**Small-world graph**

As compared to a random graph with same peer number and edge density

(1) similar pair-wise shortest path length
(2) much larger clustering coefficient
Using small-world metric

China Netcom

Date (midnight)

Average path length

Clustering coefficient

- C UUSee
- C random

- L UUSee
- L random
Fourth Question:
Fourth Question:

Does the media block distribution process essentially follow a tree-like structure?
Using edge reciprocity metrics

**Edge reciprocity**

\[
\rho = \frac{r - \bar{a}}{1 - \bar{a}}
\]

where

- \( r \) is the fraction of bilateral links over total number of directed links in the graph
- \( \bar{a} \) is the ratio of existing to possible directed links in the graph

**Tree**

\( r = 0 \) and \( \rho = -\frac{\bar{a}}{1 - \bar{a}} < 0 \)

**Reciprocal graph**

\( \rho > 0 \)
Using edge reciprocity metrics

\[ r = 0 \text{ and } \rho = -\frac{\bar{a}}{1-\bar{a}} < 0 \]

Tree

Reciprocal graph \( \rho > 0 \)
Summary of Discoveries
Modern mesh-based P2P live streaming applications scale well to large flash crowds
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P2P live streaming topologies do not possess similar properties as observed from Internet/AS-level topologies, such as power-law degree distribution
Summary of Discoveries

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ISP-based peer clusters are formed from the dynamic peer selection process
Summary of Discoveries

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P2P live streaming topologies do not possess similar properties as observed from Internet/AS-level topologies, such as power-law degree distribution

ISP-based peer clusters are formed from the dynamic peer selection process

Peers are reciprocal to each other to a great extent over mesh topologies
iqua.ece.toronto.edu

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