Overlay Monitoring and Repair in Swarm-based Peer-to-Peer Streaming

Nazanin Magharei, Reza Rejaie
University of Oregon
http://mirage.cs.uoregon.edu
Introduction

• Swarm-based (Mesh-based) P2P Streaming (SPS) of live content is very popular, e.g. IPTV
• In SPS, peers form a random overlay mesh over which they incorporate swarming content delivery
• Connectivity of the Overlay plays a key role on the performance of content delivery in SPS
  – Randomness in connectivity ensures diversity of content
• In practice, a group of peers may exhibit a stronger (biased) internal connectivity and form a cluster due to:
  – ISP Localization, regional bootstrap nodes, network-aware connections or flash crowd
• Does clustering/localization adversely affect the performance of SPS mechanisms?
In this paper

• Understanding the effect of overlay clustering (or localization) on the performance of SPS mechanisms for delivery of live content

• Propose a distributed Overlay Monitoring and Repair (OMR) mechanism that maintains proper connectivity of the overlay
Talk Outline

• SPS: Background
• Importance of Overlay Connectivity
• Effect of Overlay Clustering
• OMR Design
• Evaluation
• Conclusion
The SPS mechanism has two basic components:

- **Overlay Construction**: Peers form a randomly connected mesh where each peer has several parents and children
  - Number of parents and children of each peer is proportional to its incoming and outgoing bandwidth

- **Content Delivery**: Periodic reporting + pull requesting (swarming) through a packet scheduling scheme
• To understand the effect of overlay connectivity on content delivery
• Group peers into levels based on their shortest distance from source
• Peers one hop away from source are level 1, two hops away are level 2, ...
• The number of levels is:

\[ \text{Max\_Depth} \leq \log \frac{N}{\text{OutDeg}} \]
In a well performing packet scheduling scheme, delivery of packets has two phases:

1. **Diffusion phase**
   - Pulling packets from parents in the higher level
   - Collection of peers receive a packet during its diffusion phase form a sub-tree called **diffusion sub-tree**
   - Collection of packets delivered to a level 1 peer are called a **substr**

2. **Swarming phase**
   - Pulling packets from parents in the same or lower levels
Impact of Overlay Connectivity

- Diffusion and swarming phases for delivery of each substr enable us to derive buffer requirement
- Maximum intervals for diffusion of each substr is $Max_{Depth}$
- The number of swarming intervals for a substr to a peer depends on the relative location of its swarming parents
- In a random overlay, swarming parents may not be located at the mutually exclusive diffusion sub-trees
Swarming connections can be divided into 4 categories based on relative location of connected peers:
- $C_{ld}$, $C_{id}$, $C_{ls}$, $C_{is}$

The swarming connections between peers in different sub-trees ($C_{ld}$ and $C_{id}$) are more effective for content delivery.

- They can provide a substr in one interval.
Effect of Overlay Clustering

- What if the connectivity is not random?
- A Group of peers may connect to each other and form clusters due to many reasons (e.g. ISP localization)
- Formation of clusters causes a poor connectivity between different clusters
  - Limits the flow of content among them
  - Adversely affect the performance of content delivery
Effect of Overlay Clustering, cont.

- If all peers in a cluster become part of a diffusion sub-tree, then, swarming connections
  - within the sub-tree \((C_{ls} \text{ or } C_{is})\) increases
  - to other sub-trees \((C_{ld} \text{ or } C_{id})\) decreases

- Clustering that decreases the number of connections between sub-trees can
  - increase the number of required swarming intervals and/or
  - make some sub-trees unreachable
Effect of Overlay Clustering, cont.

- 5000 homogeneous peers, # of clusters (ISPS) = 10, Content is MDC encoded with 12 descriptions

\[
\text{CL} = \frac{\sum_{i=0}^{n} \text{InDeg}_i}{\text{Ext\_incom}}
\]

6/16/09

Nazanin Magharei
NOSSDAV 09
Overlay Monitoring & Repair (OMR)

- How can we detect the effect of overlay clustering on the content delivery?
- How can such an overlay be minimally rewired in a scalable fashion to significantly improve performance of content delivery?
- OMR: A QoS mechanism that maintains the connectivity of the overlay such that SPS operates properly
- Two components
  - Detection: identifies any problem with the overlay connectivity
  - Reaction & Repair: rewires a minimum number of connections by reacting peers
• How to detect the effect of overlay clustering?

• **Intuition**: Poor content availability is a good indicator of poor connectivity when a good packet scheduling is used
  
  – Each peer $P$ monitors its received substrs and the available substrs among its swarming parents
  
  – When peer $P$ is missing at least one substr for a given period of time, it periodically invokes the reaction and subsequently repair algorithm
Detection, cont.
Reaction

• How many peers and which ones should react?
• **Intuition**: Probabilistically increasing the effective swarming connections improves the performance in a scalable fashion
  – **How many?** Probabilistic reaction controls the number of reacting peers
  – **Who?** Biased towards peers able to achieve the most improvement due to their location in the overlay
• Reaction probability for a missing substr $r$ depends on
  – Contribution Factor (CF): % of swarming children missing $r$
  – Parent Factor (PF): % of swarming parents in the same sub-tree, missing $r$

$$\alpha \cdot \frac{1}{PF} \cdot CF^\beta$$
Repair

• Where is the repair position?

• **Intuition**: The higher levels in the missing sub-tree leads to a smaller required buffer size
  
  – Peers with a higher contribution are placed at a higher position in the missing sub-tree \( r \)
  
  – The probability for new position \( (nd) \) is computed by:

\[
1-(1- CF)^{(nd-1)}
\]
• Reacting peer traverses sub-tree $r$ in the random depth-first search fashion till reaches level $nd$ (e.g. 3)
• Reacting peer swaps one of its parents (preferably swarm) with the new parent
Performance Evaluation

- Preliminary evaluation of OMR using event-driven simulator
- The simulations are performed in multiple rounds, each round includes two steps:
  - P2P content delivery over the existing overlay
  - Running the OMR mechanism at each peer
- Resource constraint setting:
  - Source BW = Peer BW = Stream Rate
- Homogeneous and symmetric peer BW
- Peer population is 5000
- Number of clusters (ISPs) = 10
- The initial “localized overlay” has the highest level of clustering
  - External incoming BW to each cluster = Stream BW
- $\alpha=1, \beta=2$
Evaluation – Basic

How Does OMR Perform?

- Significant improvement in delivered quality mostly during the first two rounds
- Tighten the overlay effectively and reducing the buffer size
• **Connectivity between clusters significantly increases**
• About 9% of peers react in the first round and this number greatly decreases in the subsequent rounds

---

**Evaluation – Basic**

**How Does OMR Perform? Cont.**

---
• Regardless of the population, quality improves during the initial rounds.
• Larger overlays initially have larger clustering level $\rightarrow$ lower quality.
• Time to reach maximum quality is lower for larger overlay as more peers initially react to the lower initial performance.
• Content is MDC encoded
• High bandwidth peers can receive the full stream quality
• Low bandwidth peers can receive 50% of the quality
• Two scenarios of
  – SC1 80% are high bandwidth
  – SC2 20% are high bandwidth
• Low bandwidth peers require a smaller number of substrs and are less sensitive to unavailability of a particular substr.
  ➢ We primarily focus on the delivered quality to high bandwidth peers
**OMR significantly improves the quality despite heterogeneity of BW**

- Unlike SC1, the delivered quality remains relatively skewed in SC2
  - The large % of low BW peers in SC2, increases the likelihood that a high BW peer $P$ has several low BW parents or children. $\rightarrow$ decreases the value of $CF$ and $PF$ in the reaction algorithm
Conclusions

- Clustering significantly reduces the performance of live Swarm-based P2P streaming
- OMR detects poor connectivity in the overlay and reacts by rewiring minimum overlay connections
- Our preliminary simulation results
  - Demonstrate OMR is able to improve performance
  - Reveal a few more issues that requires further investigation
- Ongoing Work:
  - The effect of churn and peer bandwidth heterogeneity,
  - The effect of $\alpha$ and $\beta$ on controlling the tradeoff between responsiveness and aggressiveness
- For more information visit [http://mirage.cs.uoregon.edu](http://mirage.cs.uoregon.edu)