Collision Detection and Resolution in Hierarchical Peer-to-Peer Systems

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Outline

- Introduction
- Related Works
- Collision Detection and Resolution
- Experimental Results
- Conclusion
Introduction

- Structured P2P is a self-organized overlay network that provides efficient and scalable lookup service even when its membership changes dynamically.

- Two main types of structured P2P: flat and hierarchical.

- Flat structure organizes peer nodes into one overlay network, e.g. CAN, Chord, DKS, Pastry, Tapestry, etc.

Hierarchical P2P

- Hierarchical structure organizes peer nodes into two-level (or more) overlay networks.

  - Each node is assigned a group ID and a node ID.

  - Nodes with the same group ID form a group – second-level overlay.

  - Groups are organized in top-level overlay.

  - Each group has one or more supernodes. Supernodes are gateways to second-level nodes.
Grouping Criteria

- Administrative domain (e.g. comp.nus.edu.sg)
  - Increase administrative autonomy
  - Reduce latency
  - E.g. Brocade, Mislove et. al. 2004, SkipNet

- Physical proximity
  - Reduce network latency
  - E.g. HIERAS, HONet

- Services offered by peer nodes
  - Integration of various services in one system
  - E.g. Diminished Chord

Benefits of Hierarchical P2P

- Shorter lookup path length and better scalability
  - With \( N \) nodes and \( G \) groups, lookup path length is reduced by \( O(\log N/G) \) hops

- Reduce overhead of periodic stabilization overhead in top-level overlay
  - Stabilization refers to routing-table corrections to maintain the topology of overlay network
  - Routing table needs corrections due to membership changes
  - With \( N \) nodes and \( G \) groups, overhead in top-level is reduced by \( \Omega(N/G) \) times
Collision

- What is a collision
  - New node fails to locate existing group because topology of overlay may not be fully updated yet
  - Can result in two or more groups with the same group ID in top-level overlay

- Increase size of top-level overlay by $k$ times
  - Lookup path length increases by $O(\log k)$ hops
  - Stabilization overhead in top-level is also increased by $\Omega(k)$ times

- Proposed scheme: detecting and resolving collisions using Chord as the example

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Related Works

- Prevent collisions
  - All nodes are supernodes, e.g. HIERAS (Xu et. al., 2003), Diminished Chord (Karger et. al., 2004)
    - Every node in several overlays, including top-level one
    - Hence, stabilization overhead in top-level is not reduced
  - Grouping by admin. domain, e.g. Brocade (Zhao et. al., 2002), Mislove et. al. 2004, SkipNet (Harvey et. al. 2003)

- However, in general, collisions can occur on hierarchical structured P2P, but has not been directly addressed and evaluated, e.g. Garcés-Erice et. al. 2003, HONet (Tian et. al. 2005)
Collision Detection

- Piggyback periodic stabilization

- Reason: successful detection requires correct topology (successor pointers in Chord), and correctness of successor pointers is maintained by stabilization

- Avoid sending extra number of messages just for collision detection

Join

![Diagram of nodes with gid labels and connections]

- $g_1$
- $g_2$
- $g_3$
- $g_4$

$g_1$ and $g_2$ are connected, and $g_2$ and $g_3$ are connected, with $g_2$ being the successor of $g_1$ and $g_3$. $g_4$ is another node with gid $g_4$. The diagram illustrates the network topology and successor指针 relationships.
Join and Collision

Predecessor pointer
Successor pointer

Collision Detection

Collision is detected
Merged
Collision Resolution

- Merge two colliding groups after collision is detected
- One of the supernodes leaves top-level

Second-level nodes must be merged

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Experimental Settings

- Simulations to compare impact of collisions in hierarchical P2P system without detect & correct and with detect & correct
  - Extend Chord simulator
- Total number of peer nodes: 50,000 and 100,000 nodes
- Number of distinct groups: 1,000 and 2,000 groups
- Periodic stabilization, from every 30 seconds (on average) to 480 seconds (on average)

Impact of Collisions

- Without detecting and resolving collisions, the number of collisions grows to 3 to 12 times the number of groups
- As the impact, size of top-level overlay increases 3 to 12 times the ideal size
  - Lookup path length increases by $O(1/2 \log 12) = 1.8$ hops
  - Stabilization cost at top-level increases by $O(12)$ times
  - $G_C = kG$ denotes size of top-level with collisions
  - $G = \text{ideal size}$

\[
\frac{kG \log^2 kG}{G \log^2 G} = \frac{k \log^2 kG}{\log^2 G} = \Omega(k)
\]
Impact of Collisions (2)

Size of Top-Level Overlay ($N = 50,000$)

Impact of Collisions (3)

Size of Top-Level Overlay ($N = 100,000$)
Efficiency and Effectiveness

- Efficiency of detection is measured by average time to detect a collision
- On average, detecting a collision takes more than 10 stabilization rounds
  - This shows the importance of resolving and reducing collisions
- Effectiveness of collision detection and resolution is measured by ratio of collisions in without detect & resolve and with detect and resolve
- Our scheme reduces collisions 40% up to 98% and is more effective when performed more frequently

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- Collisions increases size of top-level overlay by $k$ times
  - lookup path length increases by $O(\log k)$ hops
  - stabilization cost increases $\Omega(k)$ times.

- Collision detection piggybacks periodic stabilization
- Collision resolution: supernode initiated and node initiated

- Simulation shows the effectiveness of our scheme in reducing collisions
- Minimize collisions to reduce cost of collision detection and resolution