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

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Outline

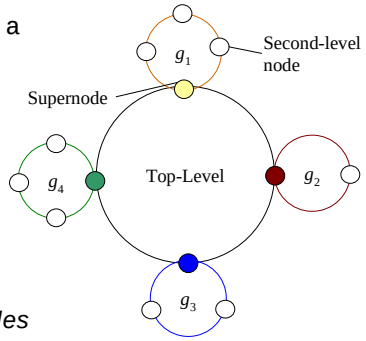
- **Introduction**
- Related Works
- Collision Detection and Resolution
- Experimental Results
- Conclusion

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

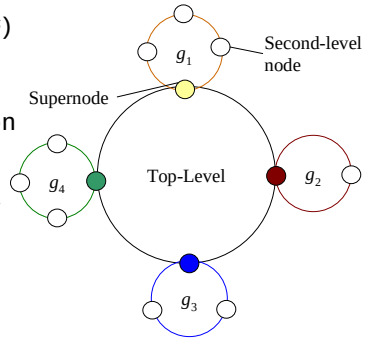


Grouping Criteria

- 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)

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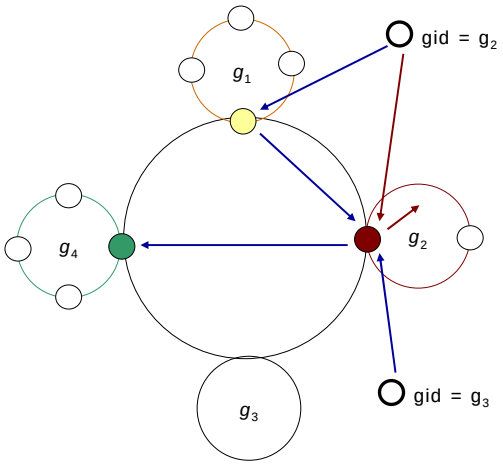
Collision Detection

- 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

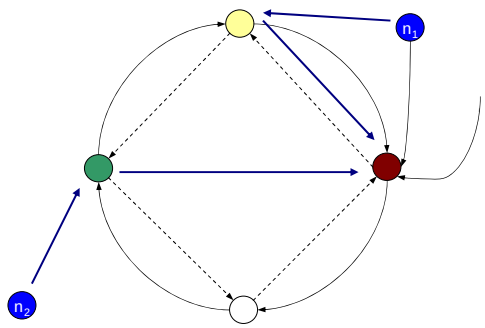
Join



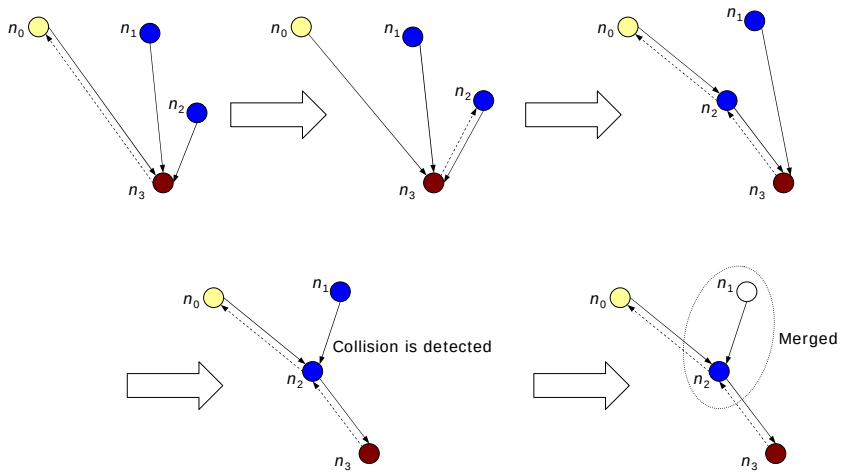
Join and Collision

Predecessor pointer

Successor pointer

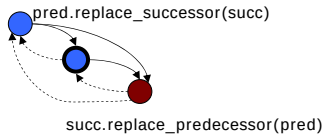


Collision Detection

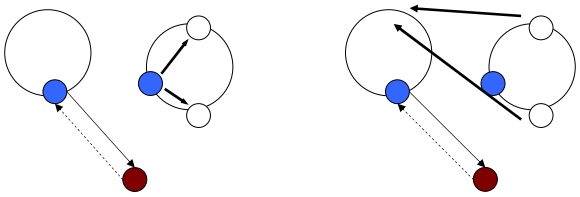


Collision Resolution

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



- Second-level nodes must be merged



Supernode Initiated Node Initiated

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Experimental Settings

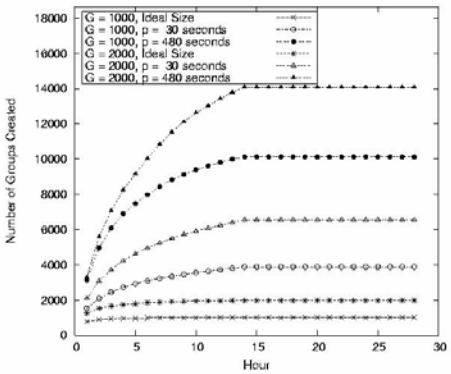
- Simulations to compare impact of collisions in hierarchical P2P system *without detect & correct* and *with detect & correct*
  - Extend Chord simulator
- Total number of peer nodes: 50,000 and 100,000 nodes
- Number of distinct groups: 1,000 and 2,000 groups
- Periodic stabilization, from every 30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

Impact of Collisions

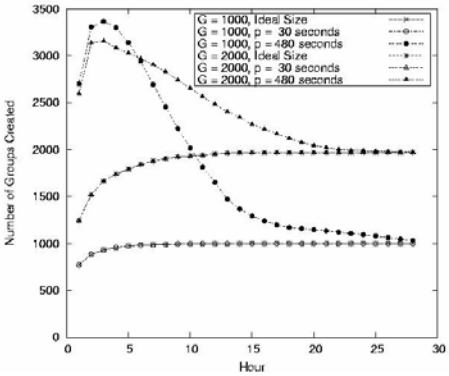
- Without detecting and resolving collisions, the number of collisions grows to 3 to 12 times the number of groups
- As the impact, size of top-level overlay increases 3 to 12 times the ideal size
  - Lookup path length increases by O(1/2 log 12) = 1.8 hops
  - Stabilization cost at top-level increases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



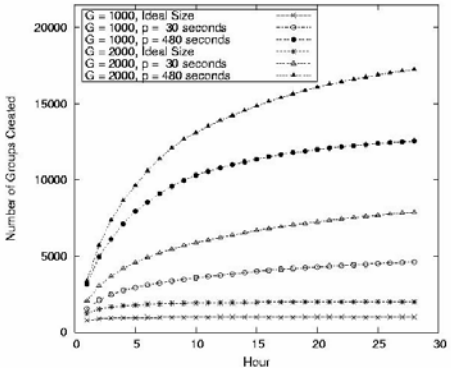
Without Detect & Resolve



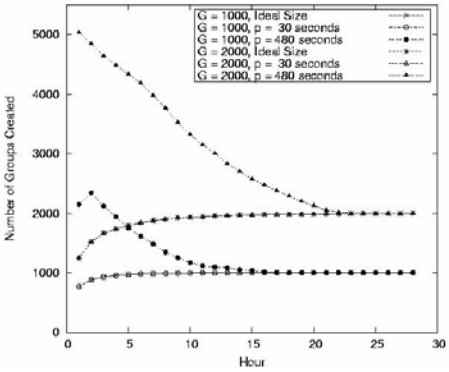
With Detect & Resolve

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

Impact of Collisions (3)



Without Detect & Resolve



With Detect & Resolve

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