SUORA: A Scalable and Uniform Data Distribution Algorithm for Heterogeneous Storage Systems

Department of Computer Science and Nimboxx, Inc.

Abstract

• A novel data distribution algorithm SUORA (Scalable and Uniform storage via Optimally-adaptive and Random number Addressing)
• A Pseudo-random algorithm
• Fairly and uniformly distribute data cross a hybrid and tiered storage cluster
• Take full advantage of the characteristics of heterogeneous devices (capacity, throughput, latency and etc.)
• Achieve maximum read throughput while keeping load balance according to data hotness and threshold

Motivation and Goals

• Massive data requires effective methods to manage them for meeting new demands
• Most data centers use heterogeneous storage combining hard disk drives HDD with emerging storage class memory SCM (e.g., solid state drives SSD and phase change memory PCM)
• Data distribution is a key issue in big data storage
• Consider distinct characteristics and merits of different devices
• Load balance and optimally-adaptive placement among devices to improve read throughput
• Data hotness is an important factor considered

Methods and Techniques

Inspired by the SPOCA and ASURA algorithms
• Assign a portion of hash space proportional to server capacity for each device and use hash functions to map data to a point in a hash space. Basic idea of SUORA
• Divide device sets into buckets with throughput
• Assign devices to segments with capacity in each bucket
• A sequence number for each data until mapping

Current Status

• Proposing three innovative algorithm models
• Completing the design details of the algorithm
• Conducting extensive analysis and evaluation
• Starting to collect I/O trace based on standard workload and benchmark
• Starting to explore further evaluation in more complex scenarios
• Plan to design an effective data I/O pattern detection and data caching strategy in an heterogeneous storage system
• Plan to implement the algorithm on practical storage system, such as Sheepdog

Project Results or Plans

• Algorithm model
• Data distribution
Step 1: data nodes are divided into two buckets, HDD bucket and SSD bucket
Step 2: each node in the bucket is assigned to segments in a number line
Step 3: all data are placed in the HDD bucket at initial placement and a random number sequence (RNS) is generated until the data fits one segment in the number line
Step 4: data distribution is automatically adjusted between HDDs and SSDs according to the hotness (read counts) and threshold
• Evaluation

Discussion

Hotness table
• Multiple hash functions for reducing hash collision
• Each bucket has an associated threshold
• Data identified as hot if counters exceed threshold
• Automatically locate data with hotness table and the random number sequence
• Reset the hotness counter periodically

Comparison: analysis evaluation of different algorithms*

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Computation Time</th>
<th>Memory usage</th>
<th>Uniform Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistent Hashing</td>
<td>Poor $O(n^{1.5})$</td>
<td>Poor $O(n^{1.5})$</td>
<td>Poor $O(n^{1.5})$, Homogeneous</td>
</tr>
<tr>
<td>Straw Buckets in CRUSH</td>
<td>Excellent</td>
<td>Poor $O(n)$</td>
<td>Good $O(n)$, By near capacity</td>
</tr>
<tr>
<td>ASURA</td>
<td>Excellent</td>
<td>Good $O(1)$</td>
<td>Good $O(1)$, Random number sequence, By capacity</td>
</tr>
<tr>
<td>SUORA</td>
<td>Excellent</td>
<td>Good $O(1)$</td>
<td>Good $O(1)$, Random number sequence, Excellent</td>
</tr>
</tbody>
</table>

* $n$ means node number and $v$ means virtual node number (for consistent hashing)

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