A Load Balancing Framework for Clustered Storage Systems

Daniel Kunkle and Jiri Schindler

Northeastern University and NetApp Inc.

Abstract. The load balancing framework for high-performance clustered storage systems presented in this paper provides a general method for reconfiguring a system facing dynamic workload changes. It simultaneously balances load and minimizes the cost of reconfiguration. It can be used for automatic reconfiguration or to present an administrator with a range of (near) optimal reconfiguration options, allowing a tradeoff between load distribution and reconfiguration cost. The framework supports a wide range of measures for load imbalance and reconfiguration cost, as well as several optimization techniques. The effectiveness of this framework is demonstrated by balancing the workload on a NetApp Data ONTAP GX system, a commercial scale-out clustered NFS server implementation. The evaluation scenario considers consolidating two real world systems, with hundreds of users each: a six-node clustered storage system supporting engineering workloads and a legacy system supporting three email servers.

1 Introduction

The basic premise of clustered storage systems is to offer fine-grained incremental capacity expansion and cost-effective management with performance that scales well with the number of clients and workloads [1,2,3,4,5,6]. To address load imbalance, most previously proposed architectures either dynamically redistribute individual data objects and hence load among individual nodes in response to changing workloads [2,5], or use algorithmic approaches for randomized data allocation (e.g., variants of linear hashing [7]) to distribute workload across cluster nodes [4,6].

However, the first approach is not well suited for enterprise storage systems. First, deployed systems typically collect only cumulative statistics over a period of time [8,9], as opposed to detailed traces with per-request timings [10,11]. Yet, systems with data migration at the level of individual objects [2,5] typically use techniques that require detailed traces to make informed decisions [12]. Second, workloads do not always change gradually. They often do so in distinct steps, for example, during consolidation when an existing system inherits a legacy system workload.

A complementary approach to balancing load across system components is to use offline solvers [8,13]. They typically use a variant of the bin-packing or knapsack problem [14] to find a cost-efficient system configuration (solution). They require only a high-level workload description [15] and capacity or performance system model. While such solvers have been shown to be effective for building an enterprise-scale system from the ground up, they are less suitable when already deployed systems grow or experience workload changes over time. Previous work proposed to iteratively apply

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A Load Balancing Framework For Clustered Storage Systems:

High Performance Computing - HiPC 2008 P. Sadayappan,Manish Parashar,Ramamurthy Badrinath,Viktor K. Prasanna,2008-12-17 This book constitutes the refereed proceedings of the 15th International Conference on High Performance Computing HiPC 2008 held in Bangalore India in December 2008 The 46 revised full papers presented together with the abstracts of 5 keynote talks were carefully reviewed and selected from 317 submissions The papers are organized in topical sections on applications performance optimizazion parallel algorithms and applications scheduling and resource management sensor networks energy aware computing distributed algorithms communication networks as well as architecture **Middleware 2011** Fabio Kon,Anne-Marie Kermarrec,2011-12-06 This book constitutes the refereed proceedings of the ACM IFIP USENIX 12th International Middleware Conference held in Lisbon Portugal in December 2011 The 22 revised full papers presented together with 2 industry papers and an invited paper were carefully reviewed and selected from 125 submissions The papers are organized in topical sections on social networks storage and performance management green computing and resource management notification and streaming replication and caching security and interoperability and run time re configuration and inspection **Load Balancing in NetApp's Clustered Storage Systems** Tho Tran,2021 To address the problem of load balancing in NetApp s storage system this thesis aims to design and implement an algorithm that results in more evenly distributed cluster reconfigurations with minimal disturbance to clients workloads I implement three different greedy algorithms to find a more balanced workload node assignment that lowers the maximum number of operations across the cluster To analyze the performance of the greedy algorithms I compare their results with those of the evolutionary and brute force algorithms I also examine whether clusters characteristics affect the algorithms performance The key findings are that the greedy algorithm with the advanced heuristic outperforms or does as well as the naive and intermediate greedy algorithms in five clusters that are representative of NetApp data However the tradeoff is that advanced greedy algorithm takes more time to run and costs more migration moves thus causing NetApp clients or support engineers the inconvenience of manually moving multiple workloads On the other hand the naive greedy algorithm performs well on large clusters that primarily have small non dominating workloads but is more likely to get stuck in local minimums when it comes to small clusters that have one or more dominating workloads The intermediate algorithm performs as well as the naive greedy algorithm in these clusters Finally the evolutionary algorithm is suitable for clusters with fewer nodes and workloads Based on these findings it is recommended that NetApp should use the naive greedy algorithm to balance large clusters that mostly have small non dominating workloads If clusters have one or more large dominating workloads then it is best to use the advanced greedy algorithm to do load balancing *High Performance Cluster Computing* Rajkumar Buyya,1999 This book offers experts on programming and applications for commodity supercomputers It is organized into three areas programming environments and development tools Java for high

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