

A Load Balancing Framework for Clustered Storage Systems

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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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Table of Contents A Load Balancing Framework For Clustered Storage Systems

1. Understanding the eBook A Load Balancing Framework For Clustered Storage Systems
 - The Rise of Digital Reading A Load Balancing Framework For Clustered Storage Systems
 - Advantages of eBooks Over Traditional Books
2. Identifying A Load Balancing Framework For Clustered Storage Systems
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an A Load Balancing Framework For Clustered Storage Systems
 - User-Friendly Interface
4. Exploring eBook Recommendations from A Load Balancing Framework For Clustered Storage Systems
 - Personalized Recommendations
 - A Load Balancing Framework For Clustered Storage Systems User Reviews and Ratings

- A Load Balancing Framework For Clustered Storage Systems and Bestseller Lists
- 5. Accessing A Load Balancing Framework For Clustered Storage Systems Free and Paid eBooks
 - A Load Balancing Framework For Clustered Storage Systems Public Domain eBooks
 - A Load Balancing Framework For Clustered Storage Systems eBook Subscription Services
 - A Load Balancing Framework For Clustered Storage Systems Budget-Friendly Options
- 6. Navigating A Load Balancing Framework For Clustered Storage Systems eBook Formats
 - ePub, PDF, MOBI, and More
 - A Load Balancing Framework For Clustered Storage Systems Compatibility with Devices
 - A Load Balancing Framework For Clustered Storage Systems Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of A Load Balancing Framework For Clustered Storage Systems
 - Highlighting and Note-Taking A Load Balancing Framework For Clustered Storage Systems
 - Interactive Elements A Load Balancing Framework For Clustered Storage Systems
- 8. Staying Engaged with A Load Balancing Framework For Clustered Storage Systems
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers A Load Balancing Framework For Clustered Storage Systems
- 9. Balancing eBooks and Physical Books A Load Balancing Framework For Clustered Storage Systems
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection A Load Balancing Framework For Clustered Storage Systems
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine A Load Balancing Framework For Clustered Storage Systems
 - Setting Reading Goals A Load Balancing Framework For Clustered Storage Systems
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of A Load Balancing Framework For Clustered Storage Systems
 - Fact-Checking eBook Content of A Load Balancing Framework For Clustered Storage Systems
 - Distinguishing Credible Sources

13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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