Abstract

Data center storage architectures face rapidly increasing demands for data volume and Quality of Service (QoS) requirements today. Hybrid storage systems have turned out to be one of the most popular choices in fulfilling these demands. A mixture of various types of storage devices and structures enables architects to address performance and capacity concerns of users within one storage infrastructure. Nowadays, the hybrid storage system that utilizes SSD as the performance tier or cache and HDD as the main storage is still the main stream in data center system. With the performance and price gaps between different storage devices, the hybrid storage architecture will continue to be important in the future storage system design. There are lots of architectures, such as tiered storage, cache storage, etc. and policies, such as cache policy, replacement policy, etc. in the hybrid storage system, it is difficult to use a general mathematical model to capture all the features of the storage architecture. Therefore, we combine the simulation and modeling with cross verification to design an intelligent storage system with suitable caching algorithm.

In the hybrid storage system, besides the performance requirement, the size of capacity the storage system can provide is also important. Shingled Magnetic Recording (SMR) drives have unique features different from conventional disk drives, e.g., append-only (sequential) write, indirect address mapping and garbage collection. Batch process is also designed to fully utilize the sequential write property to improve the SMR drive performance. The selection of different system parameters and policies affects the system performance and capacity efficiency. However, there is no dedicated analytical tool available so far to guide the parameter and policy selection. Thus, an analytical model of SMR drive is built based on queuing model to fill the gap, and simulation is further

conducted to validate the model and check the effects of different drive parameters. We illustrate the similarity of the analytical and simulation results, and show that our tool can be utilized as the guide of the SMR drive design

In an SMR drive, due to its append-only write property, the data update is usually handled through a log-structured manner, which causes old data to become invalid and dirty. Garbage collection (GC) methods are therefore introduced to clean the dirty data to release the disk space. However, the necessity of GC process performed remains an issue, as the process may increase the power consumption and downgrade the performance. Thus our emphasis in this paper is placed on the decision of the process under different workload conditions and system settings for overall power consumption reduction and disk space saving. An analytical model is built to study various scenarios, and a simulator is further developed to verify the correctness of the model.

The SMR drive plays an important role in the hybrid storage system. To evaluate and compare the performance of different types of hybrid storage systems, a flexible hybrid storage system simulator is designed and developed to simulate various kinds of hybrid storage architectures and algorithms. The architectures include SSD tiering method, SSD caching method and SSD hybrid method, and the algorithms include different types of cache policies, such as read-only and write-back, and different kinds of hot data identification and data migration policies. The performance of these architectures and algorithms are evaluated and compared under different types of workload environment, and the results can be utilized as a guide for future hybrid storage system design, and a benchmark for analyzing the other types of hybrid storage systems, which are the extension of these basic storage architectures.

In a hybrid storage system, the caching policies, such as hot/cold identification and data migration flow controlling, play an important role that affects the system performance. Based on the storage system simulator, we can easily design and improve the caching policies inside a hybrid storage system to improve the system performance. In particular, the migration size is one of the key factors. Fixed size of data migration generally cannot provide good performance when the workload properties change significantly. We design a hybrid caching algorithm based on fuzzy control and decision tree which

can adaptively adjust the data migration policies according to the workload properties. The fuzzy rules can be automatically generated through the training process of decision tree classification and regression. From the simulation, we show that the hybrid disk performance can be improved up to 20% for dynamically changed workload.

Meanwhile, traditional hybrid storage system only combines the performance tier with faster access speed and higher cost and the capacity tier with larger capacity and lower cost becomes popular to meet the increasing requirements of data volume and QoS. However, these storage systems do not fully utilize the sequential access properties and the non-limited write cycles of HDDs. This paper reveals a new approach to configure HDD and SSD in a novel hybrid structure such that the advantages of both sides can be fully utilized, i.e., the fast IO access of SSD (in particular for random access) and the non-limitation of write cycles of HDD. By carefully designing the disk data stripes, the (sequential) performance requirement for HDDs and SDDs can be matched in a certain degree. Therefore, they can be used in the same array/pool without considering the high/low tiers or fast/slow cache. Due to the performance match of sequential access in general, this design is more suitable for SMR drives (or CMR with MBC). This structure can then be further applied to RAID and EC schemes.