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Dynamic Storage Tiering:

The Integration of Block, File and Content

Hitachi Virtual Storage Platform with Hitachi Dynamic Tiering software, Hitachi NAS Platform and Hitachi Content Platform Enhances Performance and Increases Storage Efficiency

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Hitachi Storage Solutions

◎**Hitachi Data Systems**

Table of Contents

Executive Summary

The amount of data being created and stored is increasing at a phenomenal rate and a large amount of it will never be accessed again. An increasing amount of data must be kept for extended periods for audit and to comply with regulations. At the same time, the growth in server virtualization has resulted in more and more machines, physical and virtual, that need to access storage assets at an almost uncontrollable rate.

These challenges have driven IT organizations to solutions that use lower cost tiers of storage. In this new storage environment, how do storage administrators maximize the efficiency of the storage infrastructure to take advantage of the most cost-effective storage assets?

Advances in storage technology and the adoption of high performance computing concepts in storage systems have resulted in innovative solutions to address these challenges. For example, the Hitachi Virtual Storage Platform is designed to be one platform for all of your information, whether block, file or content. It is the only storage architecture that flexibly adapts for performance and capacity, and it extends to multivendor storage.

Furthermore, the Virtual Storage Platform supports dynamic tiering of storage. It optimizes the use of high performance tiers and takes maximum advantage of low cost tiers.

Hitachi Dynamic Tiering enhances the storage administrator's ability to utilize storage that has different performance, capacity and reliability characteristics to optimize overall performance. It automates the movement of data to the appropriate tier at a fine grain level. This ensures that even within a volume or file, highly referenced data is available on the highest performing devices. Data that is infrequently referenced is migrated to lower performing, lower cost drives.

Starting with the Virtual Storage Platform, the combination of Hitachi NAS Platform, powered by BlueArc®, Hitachi Content Platform and Hitachi Dynamic Tiering is a comprehensive solution that ensures data is kept on the most cost-effective media. It automates the movement of unused and archival data to a content management system that can eliminate duplicate data and meet long-term data retention requirements.
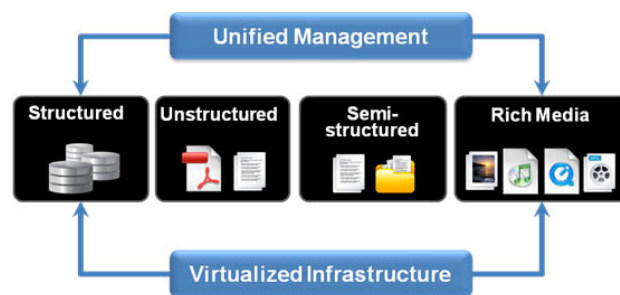
Introduction

Most data is rarely or never accessed after it is created. As a result, it should not be stored on your most expensive tier of storage, but moved to a lower, less expensive storage tier. Managing the movement and placement of data is the promise and premise of data lifecycle management methodologies. However, defining where and for how long data should reside at any point in its lifecycle can be complex and problematic. With the introduction of the Hitachi Virtual Storage Platform, Hitachi has introduced Hitachi Dynamic Tiering software. Hitachi Dynamic Tiering is a revolutionary new solution that eliminates the time consuming manual processes of data classification and movement to different storage tiers. It optimizes tiered storage usage while actually improving performance.

The Virtual Storage Platform is the only 3D scaling storage platform designed for all data types. The system can scale up for increasing workloads, scale out for the highest performance and capacity growth, and scale deep for extending the value of legacy and adding lower cost storage. It supports all data types, integrating file, content and block storage on a single platform (See Figure 1.). The Virtual Storage Platform is the only storage architecture that flexibly adapts for performance and capacity while also managing and virtualizing external multivendor storage. With unique Hitachi Command Suite management capabilities, it provides a key element of enabling the transformation of the data center.

This storage platform supports dynamic mobility of data across virtual storage tiers for block, file and content data. Its host transparent migration capability, managed within the storage controller, greatly reduces outage windows and operational overhead, and increases storage administrator productivity. Its highly efficient data center design delivers the best performance and capacity, reduces the footprint per terabyte and lowers power consumption and cooling requirements. Additionally, its integration with Hitachi NAS Platform, Hitachi Content Platform and Hitachi Data Discovery Suite creates an integrated tiered storage solution unmatched in the industry.

Figure 1. Hitachi Virtual Storage Platform: Support for All Data Types

In this extended, virtualized Hitachi environment, active application data can now be moved online dynamically, without disruption. This supports data lifecycle management, maintenance, system migration and increased performance. And now, with Hitachi Dynamic Tiering, operations can be greatly simplified because its automation eliminates time consuming manual processes of data classification and movement to optimize the use of tiered storage.

This paper examines the key features of Hitachi Dynamic Tiering, Hitachi NAS Platform and Hitachi Content Platform. Through use cases it highlights the benefits of using Dynamic Tiering with raw block storage, NAS Platform by itself and then with Content Platform for archiving.

Block Storage, File Systems and Content Platforms

Block Storage

Many enterprise applications keep their files and databases on raw block storage. While this can provide very fast access, it puts the responsibility on the storage administrator to manage space utilization, storage allocation, provisioning, and determination of and movement to the optimal class or tier of storage. With today's staffing and budget constraints and the skill and experience needed to do this effectively, it has become almost impossible for the IT staff to accomplish these tasks effectively.

Network File Systems

Network File Systems move disk storage for files out of the local server onto a separate storage unit connected to the network. They simplify management of and shared access to the storage for multiple servers and applications. File systems provide greater access to the data and more flexibility, as well as independence from server failures.

A drawback of file systems is the large amount of data that is created and stored. Most data files are used shortly after their creation and are never accessed again. However, they remain on the storage device. Conventional solutions for file systems have difficulty delivering the increasing demand in performance, capacity and ease of management.

Content Platforms

Content platforms support large object-store capacities or active archiving and storage for static inactive data. They are essential to a long-term data retention policy. These platforms may include compression, de-duplication, backup reduction and cloud infrastructure enablement to optimize quick access to and use of the data over the Internet.

Moving static inactive data from active storage such as file systems or raw block storage can reduce the working set of data on more expensive storage. It can improve data access performance while saving capacity due to data compression and de-duplication. Content platforms can help organizations lower storage capital expenditure (CAPEX) and operating expenditure (OPEX) while providing good long-term storage for data and helping meet legal requirements for data retention.

Storage Tiering

Tiered Storage

Different classes of storage are available with different cost and performance characteristics, such as drive type, speed and RAID configuration. It is possible to create tiers of storage based on

the devices' different characteristics. These storage tiers let organizations use their storage more efficiently and reduce costs. Most tiered storage solutions today require the storage administrator to manually classify data and schedule the movement of data before they can use storage more efficiently and eventually reduce cost.

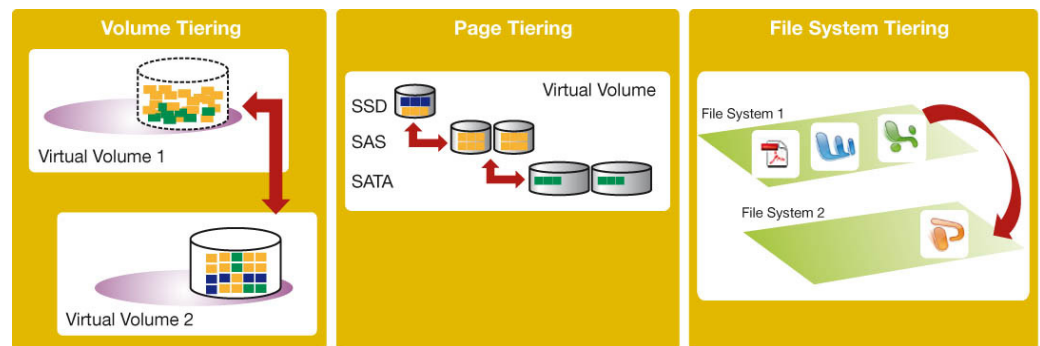## Tiered Storage for Files, Volumes and Pages

File tiering or file migration between tiers refers to the movement of files or content between storage tiers using compatible file systems. The tiers may reside within the same storage system or separate storage systems connected through a network (See Figure 2). Volume and page-based tiering or migration applies to block-based environments, which in turn are used by higher level file and content interfaces.

With volume-based tiering, a complete storage volume is moved or migrated between tiers. The tiers may include:

- High performance, expensive storage, such as solid state disk (SSD)
- Good performance storage, such as Fibre Channel or SAS
- Low cost, high capacity storage, such as SATA
- Even tape or optical drives

Page-based tiering offers a finer granularity of tiering within a designated volume. Any page for a volume can dynamically reside on any tier. Page-based tiering always occurs independently and transparently from the host application server(s), whether it is presented as block or file level storage.

Figure 2. Volume, Page and File System Tiering

Policy Management of Files with Tiered Storage

Managing tiered storage and ensuring that files are located on the right tier can be time consuming. However, with the addition of policy managers for tiered storage systems, the storage administrator can define policies to automate the movement of data and files between tiers based on scheduled intervals. The policies can be based on specified attributes, such as data age or usage. This can improve disk performance, reduce storage costs and improve the productivity of storage administrators.

Hitachi Virtual Storage Platform: One Platform, All Data

The Hitachi Virtual Storage Platform is an enterprise storage system that can support not only block data types, but also file and content data types. This platform can support all three environments concurrently. It has a maximum capacity of 2.6PB of internal storage, up to 192 front-end ports for host connectivity, 2048 disk drives and the 3D scaling architecture. This platform optimizes performance, capacity and connectivity for block data, file systems and objects for archiving in a single platform at the same time.

Hitachi Dynamic Tiering Software

Hitachi Dynamic Tiering (HDT) takes the automation of tiered storage to a new level. It enables the management of multiple storage tiers as a single entity. It presents a new kind of virtual volume with embedded smart tiering that monitors access and moves data at the fine grain page level. It breaks the volume into pages and automatically promotes the pages that are being referenced frequently, avoiding the time and storage space to move the entire data set or file. It self-optimizes for high performance and space efficiency in order to have the right data in the right place at the right time.

HDT uses a dynamic storage pool, which is divided into pages. Virtual volumes are made up of pages from the dynamic storage pool. The pages are mapped to tiers within the pool. The pages can be anywhere in the pool on any tier within that pool. The Virtual Storage Platform, through the HDT software, determines which pages it is best to place in higher tiers and which in lower tiers. The pages can be moved up and down between the tiers within the pool for performance optimization purposes. In operation, an HDT environment will have most of the highly referenced pages in the highest tier and the least referenced pages in the bottom tier. HDT will try to use as much of the higher tiers as possible. This can provide the effective appearance that all the data is on the fastest tier of storage while in fact most of the data resides on lower cost, lower performance storage tiers composed of SAS and/or SATA drives. The lowest tier also contains much of the spare capacity. By default, HDT software automatically initiates page migration periodically. However, the storage administrator can change this to manually initiate the migration between tiers.

HDT volumes are just another kind of volume in a tiered storage architecture. Just like disk types and RAID configurations, HDT multitier volumes are another way of delivering tailored storage cost and performance service levels. These dynamically tiered volumes do, however, deliver superior service levels at less cost, maximizing service levels and minimizing storage total cost of ownership (TCO). Capacity can be dynamically added to or removed from any tier at any time, which means that sizing a tier for a pool is much easier.

HDT and SSD make an excellent match. SSD storage delivers excellent performance but is relatively expensive when compared to SATA storage or even SAS storage. Organizations typically opt to purchase less SSD capacity than they do SAS or SATA. The challenge they then face is how to make the best use of the SSD storage they do purchase. With HDT, this is no longer a problem. By defining the SSD storage as the highest tier, the system will use this storage for those pages that are the most active. It will move less active storage to lower tiers and the lowest activity storage to the lowest tier. Pages will migrate to the appropriate tier based on their usage. Because HDT only moves the highly referenced pages, a smaller amount of high performance disk, such as SSDs, can significantly improve the storage system performance.

With HDT, the storage administrator does not need to classify data or define policies; once the tiers are configured, the storage system does all the work, freeing up the storage administrator to focus on other storage related responsibilities.
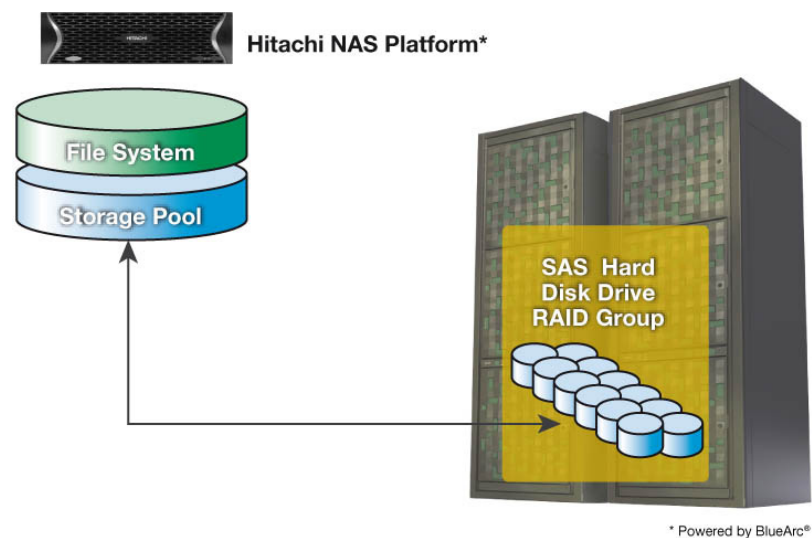
HDT is very good for database applications and can improve performance for databases stored in a file system. It does this by keeping the highly referenced data, such as control tables and indexes on highest storage tier and moving less frequently reference pages to a lower tier of storage. HDT is also excellent for rich media applications. The self-adjusting system can optimize performance based on demand, letting content service providers manage their storage assets more effectively and use less expensive, higher capacity disk drives, such as SATA drives.

Hitachi NAS Platform

The Hitachi NAS Platform interfaces with the Virtual Storage Platform to consolidate unstructured data (see Figure 3). This enables highly efficient content indexing and intelligent file tiering that support policy-based migration of data and content among storage and archive tiers. This fulfills the promise of one platform for all data.
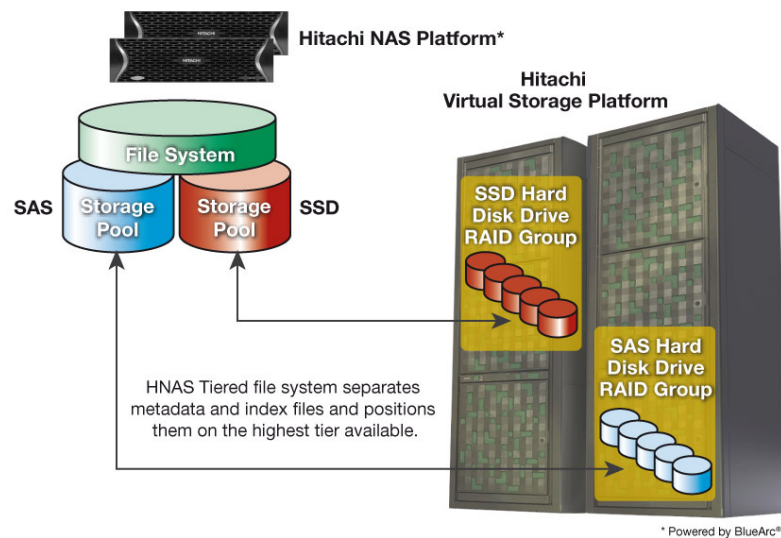
With leading performance and scalability, the Hitachi NAS Platform allows you to consolidate third party NAS devices or file servers to simplify your IT infrastructure. You can also reduce the complexity of storage management and lower your TCO. The advanced virtualization and dynamic provisioning capabilities significantly improve efficiency, agility and utilization across file sharing environments. The native policy manager software lets administrators determine when and where to move the files or folders, and how often.

Figure 3. Hitachi Virtual Storage Platform with Hitachi NAS Platform

Intelligent file tiering software for Hitachi NAS Platform helps organizations move data among storage and archive tiers with automated, policy-driven migration tools. It enables policy-based hierarchical storage management (HSM) within the Hitachi NAS Platform. With intelligent file tiering, the job of the storage administrator is to classify and segregate data, create storage tiers with separate file systems, and then create the policies to manage and move the files to the appropriate tier. Automation through policies significantly reduces the administrator's workload once the policies are defined. However, they do need to monitor and classify the files to ensure that the policies are correct or determine whether additional policies should be created to handle specific situations.

Figure 4. Hitachi Virtual Storage Platform with Hitachi NAS Platform and Tiered File System

Tiered file system is a recently added feature of the Hitachi NAS Platform 3080 and 3090 models. Its optimized metadata handling option lets administrators use fewer high speed disks combined with lower cost disks and still achieve the same industry-leading performance that Hitachi customers have come to expect (see Figure 4). It delivers this efficiency by automatically separating the metadata from the user data and placing the metadata on the fastest tier of storage being used (SAS or SSD). It then places the rest of the user data on the slower, less expensive tier. In turn, metadata operations are accelerated to improve overall system performance, while reducing the amount of high performance storage required. Metadata is the "data about data." While it is a small percentage of the total file system, the number of metadata operations is many times the regular data operations and contributes to a higher share of the I/O overhead.

Hitachi Content Platform

The Hitachi Content Platform further extends the scope of the Hitachi Virtual Storage Platform. It provides distributed object storage technology that is ideally suited to the management, long-term preservation, distribution and retention of data from a variety of content sources. These sources are Microsoft® Exchange Server, Microsoft SharePoint, Oracle, SAP and many more. The Hitachi

Content Platform also complements the Virtual Storage Platform by serving as an intelligent active archiving tier. It enforces regulatory policies, maintains integrity of the data, automates retention practices, provides a searchable environment for e-discovery, compresses and de-duplicates data for storage efficiency. It also delivers superior data protection and disaster recovery over tape-based backups.

Dynamically Tiered Storage in the Real World

Storage Administrator Challenges in Optimizing Storage Utilization

In today's storage environment there are several options for where data should be housed. Legacy and high performance enterprise applications such as online transactional processing (OLTP) tend to use SAN attached, raw disk storage, i.e., block storage. Desktop applications and many business applications that share files are housed in file systems and tend to use network attached storage (NAS). Less frequently used data is archived, moved to less expensive storage or backed up to tape. Each of these solutions has required storage administrators to monitor and classify the various files and datasets to optimize performance and storage utilization.

Static Tiering with Block Storage

Many enterprise applications store their data in datasets as blocks of storage on raw disk storage devices without the use of file systems. These applications use only the basic disk management provided with the operating system or by the external storage platform to allocate storage blocks, maintain the directory of which blocks belong to each dataset and set up and manage RAID arrays of disk. In this environment, managing the allocation of disk space and the placement of datasets is the responsibility of the storage administrator. These individuals are responsible for classifying and segregating the datasets and placing the most important or most active data on the highest performance drives to maximize system performance. They often have to manually move the datasets to different LUNs or different areas of a LUN to optimize overall system performance. Moving the data can be disruptive and the associated applications may have to be stopped and the server configuration changed to reflect the new allocation and the server rebooted.
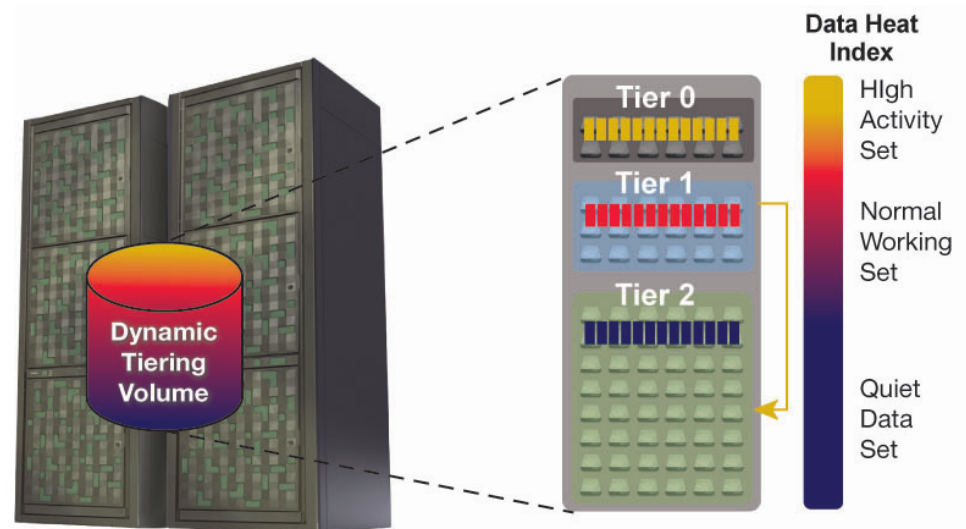
Dynamic Tiering with Block Storage

With storage tiering, the administrator can take advantage of the different characteristics of storage media such as drive type, speed and RAID level. However, they still have to do the classification and manage the allocation and migration of the data to the correct tier. Management tools such as Hitachi Tiered Storage Manager and Hitachi Dynamic Provisioning software handle much of this workload. But it is still a scheduled function and operates at the volume level even though different parts of the dataset have different usage characteristics.

It is not feasible for the storage administrator to try to determine what sections of a volume are accessed frequently. Without this information they cannot move those blocks to higher cost, high performance drives (such as SSD) and move the rest of the dataset to lower cost, high capacity SATA drives.

With the Hitachi Virtual Storage Platform, Hitachi Dynamic Tiering manages the tiering dynamically

(see Figure 5). It monitors and manages space utilization at a fine grain page level rather than at the file or dataset level. This means that only frequently referenced parts of a file or dataset will reside on the highest tier of storage, minimizing the amount of tier 0 storage required for the highly referenced data.

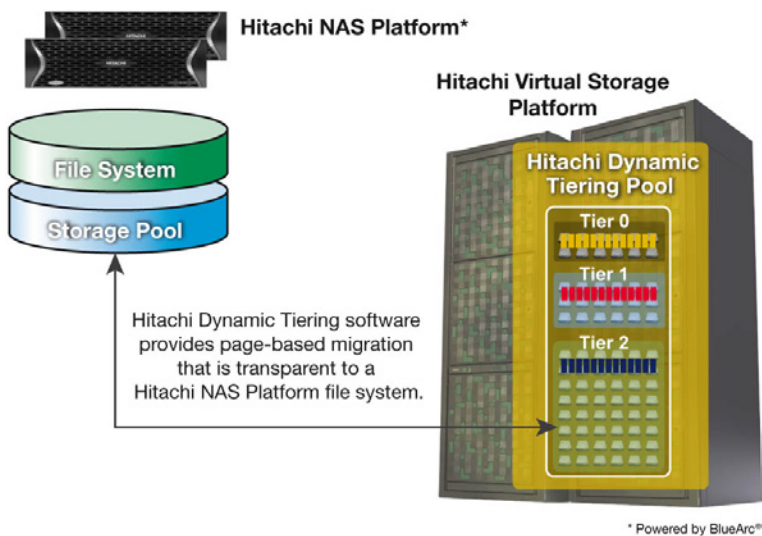Figure 5. Hitachi Virtual Storage Platform with Hitachi Dynamic Tiering Volume

HDT identifies hot spots of frequent access and moves them to the highest tier of storage to improve performance. It also moves less frequently referenced pages to lower tiers of storage. All of this occurs with complete transparency to the application. No application has to be changed. No special processes have to be defined and storage administrators do not have to monitor disk utilization and manually move files or datasets. With HDT, data is dynamically migrated at the page level across the storage tiers, based on utilization. From an application's perspective, all its data is on high speed storage because as pages are frequently referenced, they are moved to the highest tier. In this way, the overall cost and performance of the storage platform is optimized.

Hitachi NAS Platform and Hitachi Dynamic Tiering

There has been a massive increase in the number of desktop users, application servers, virtual blade servers and computing clusters over the last 10 to 15 years. It has become extremely resource intensive to manage the storage allocation and file sharing privileges using raw block storage or a host-based file system. In addition, a single host- or server-based file system cannot scale the performance or capacity required by the growing number of users.

The integration of Hitachi NAS Platform with the Virtual Storage Platform and HDT software creates an architecture that takes tiered storage to a new level (see Figure 6). For the first time, users can benefit from automated tiering within a single file system as well as page-based tiering within volumes on which the file system rests.

Allocating space for Hitachi NAS Platform volumes has become much easier. A storage administrator used to have multiple volumes with each allocated on different types of disk drives for different tiers of storage and used to move files between file system tiers. Now the storage administrator can allocate a volume for HDT provisioning and let HDT manage the movement of data between tiers based on activity. This delivers better performance and reduces the storage administrator's workload. Additionally, Hitachi Dynamic Provisioning software can be used to allocate a large HDT volume, but only provision the physical storage for the volume, as it is needed. This reduces the actual physical storage requirements, allowing acquisition of new disk drives to be postponed until they are actually needed.

Hitachi NAS Platform tiering requires a separate file system for each tier. However, with HDT you can consolidate those separate file systems into a single tiered volume using a single file system. It utilizes the storage more efficiently and reduces the complexity of taking snapshots and doing backups because there are fewer tasks to set up and manage. The snapshot or backup will copy all of the data from all tiers in the file system. This is possible because all of the tiers are contained within the single volume that makes up the file system, rather than each tier being in a separate file system with separate volumes. This reduces the setup and management of these tasks, reducing the workload of the storage administrators so that they can focus on other aspects of storage administration that may have been deferred.

HDT not only improves the productivity of the storage administrators, it also makes more efficient use of your storage assets. Use of the highest tiers of storage is maximized by fully allocating them with the pages that are most frequently referenced, allowing the best performance. In addition, you can deliver SSD level performance to all of your applications and users while actually investing in only a minimal number of drives. Data is migrated to this highest tier while it is highly referenced and then migrated back to a lower tier when it is no longer active, freeing up this prime space for newly active data.
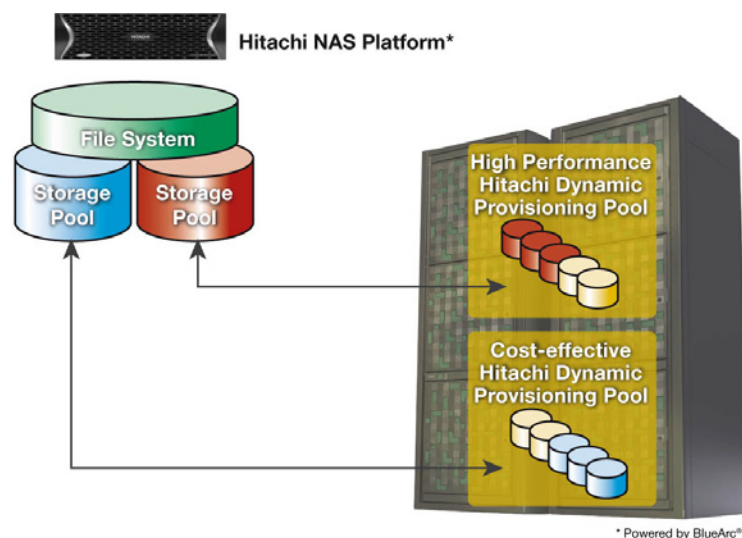
Hitachi NAS Platform with Hitachi Dynamic Tiering and the Tiered File System

Hitachi NAS Platform and Hitachi Dynamic Tiering together deliver overall performance and reduce the storage administrator's workload. However, there is a situation where adding the use of the NAS Platform policy manager and the HNAS tiered file system to the configuration can improve performance for certain classes of data (see Figure 7). The movement of pages between tiers of an HDT volume is based on past activity as reflected in a heat index. As page accesses occur, the heat index will monitor this activity and at the next scheduled page migration, pages may be moved to a higher or lower tier. Movement of a page does not occur immediately when there is access to a page. It occurs on a periodic basis and the need to move a page is determined from the heat index, which reflects the page activity during the prior period. This periodic movement of pages improves the overall storage platform performance and avoids "thrashing" that could occur if movement happened too frequently.

If there is a need to periodically, asynchronously promote data to a higher tier for processing you can use the NAS Platform policy manager and tiered file system. This will improve performance even more and is possible because page movement within an HDT volume is based on history.

To take advantage of both the tiering in HDT and the capability of a tiered file system to place key data on the best performing volume, the storage administrator would create two HDT volumes. One of them would be the high performance volume and have SSD and SAS drives assigned to it. The second volume would be the cost-effective volume and would have SAS drives and SATA drives. Tiered file system would use the high performance volume for the file system metadata, ensuring it is always available on the highest performance volume while the actual files could be saved on the cost-effective tier.

Figure 7. Hitachi NAS Platform with Hitachi Dynamic Provisioning Software and Tiered File System

When the data must be promoted for maximum performance, the policy manager is used to move the entire file to the high performance tier. After the need has passed it is moved back. In short, the bulk of the file (the data portion) changes since the tiered file system already has the metadata on the performance tier, what changes is the bulk of the file, the data portion.
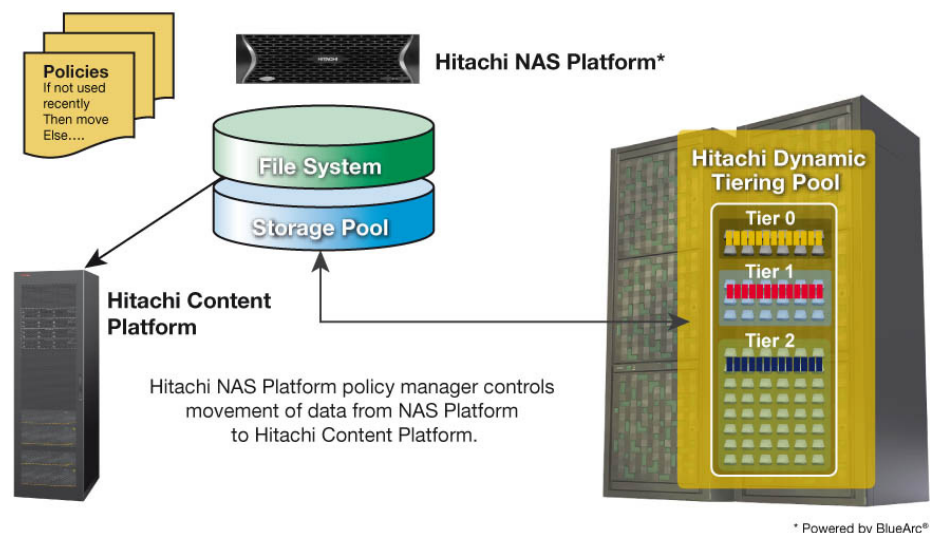
Hitachi NAS Platform and Hitachi Content Platform with Hitachi Dynamic Tiering

The massive growth in data, both structured and unstructured, is challenging companies of all sizes. Specific challenges include:

- Management of active versus inactive storage
- Determination of the type of storage to use for the data
- Management of which data and how much data is backed up
- Management of the growth of physical media to maintain the backed up data

These are complex challenges that require experience and skill to address effectively. There are also business, legal and compliance requirements to retain data so that it is accessible in its original form, for years or decades. Because of this it is useful to create a separate archive tier for long-term, low-activity data. But managing the movement of data from active status to backed up or archived status can be daunting. Manually classifying the datasets and scheduling their migration to archival storage is no longer feasible for many companies.
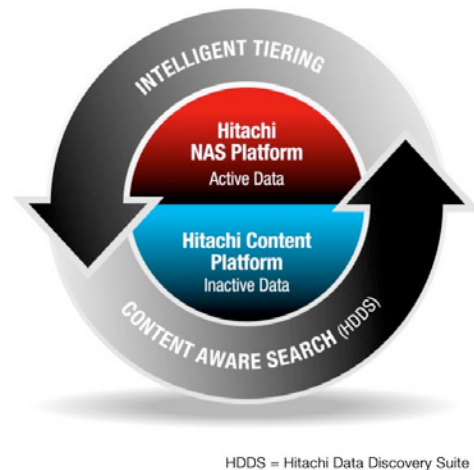
Figure 8. Hitachi Virtual Storage Platform with Hitachi NAS Platform, Hitachi Dynamic Tiering and Hitachi Content Platform

The combination of Hitachi Virtual Storage Platform with Hitachi NAS Platform, the Hitachi Content Platform and Hitachi Dynamic Tiering optimizes storage performance and space efficiency for the active NAS environment. It also provides a final, long-term storage archive tier. Administrators can

avoid spending valuable storage administrator resources to classify files and build policies to manage tiered storage. With NAS Platform and HDT, the administrator only has to create HDT volumes for NAS Platform data and a normal volume for Content Platform. The NAS Platform and Content Platform volumes will use Dynamic Provisioning software to use only the physical storage that it actually needs. However, for the NAS Platform volumes, the administrator creates the volume, allocates different types of storage, e.g., SSD, SAS and SATA, to the volumes as appropriate, and defines the tiers. HDT then optimizes storage usage and performance according to the applications service level requirements, determining which data is on which tier and migrating it as necessary. In conjunction, using the intelligent file tiering feature of NAS Platform, the storage administrator creates policies for migrating old files or folders for archiving from the NAS Platform to the Content Platform volume based on defined company criteria for archiving or long-term storage. The policy manager actually takes care of moving the files or folders to the Content Platform (see Figure 9).

Figure 9. Intelligent File Tiering with Content Aware Search Moves Files to Hitachi NAS Platform and Hitachi Content Platform

HDDS = Hitachi Data Discovery Suite

This combination of NAS Platform and Content Platform with HDT dramatically reduces operational overhead for managing NAS Platform migration policies and optimizes storage utilization and long-term, archival storage.

Summary

The Hitachi Virtual Storage Platform and tiered storage can help you transform your data center. A major challenge facing all IT organizations is how to manage and make efficient use of storage while meeting the company's need to improve productivity, reduce costs and increase the return on assets. The Hitachi Virtual Storage Platform is the solution for meeting this challenge.

On the Hitachi Virtual Storage Platform, Hitachi Dynamic Tiering helps storage administrators effectively manage the use of storage assets to ensure that the best performing storage is used for the most highly referenced data. It provides the best overall performance and throughput at a

system level. Hitachi Dynamic Tiering software monitors storage usage and moves data based on frequency of reference. The most frequently referenced data is moved to and maintained on the highest tier, which is the best performing storage. Less frequently referenced data is migrated to lower performing, lower cost storage and is kept there until it is referenced more often.

Hitachi Dynamic Tiering can optimize the performance of both block storage and the Hitachi NAS Platform while effectively utilizing multiple disk technologies with different performance, capacity and cost characteristics. When the NAS Platform uses the Virtual Storage Platform as its back end storage, Dynamic Tiering can improve the productivity of storage administrators. It does this with defined attributes that eliminate the need to create and maintain policies to manage which files are moved to which tier. While Dynamic tiering manages pages based on access, the NAS Platform along with tiered file system manages files and efficiently separates metadata from usable data. Policy-based file migration can be combined with Dynamic Tiering capabilities to provide unprecedented storage efficiency and performance.

When combined with the Hitachi Content Platform, the Hitachi NAS Platform can use a combination of dynamic tiering and the policy manager. The tiering of active data is managed with dynamic tiering and inactive data is managed using the policy manager to move the inactive or archival data to the content platform. This optimizes the use of the NAS Platform and ensures that, when appropriate, data is archived to the Content Platform.

In keeping with the Hitachi Data Systems strategy of one platform for all data, the Hitachi Virtual Storage Platform with dynamic storage tiering is a powerful management tool for all types of data. The data can be on raw storage as blocks of data or in a file system as objects or files. With Hitachi, storage administrators now have a new choice of how to best enhance performance and utilization for block, file and content.

◎ Hitachi Data Systems Corporation