White Paper

STORAGE TIERING FOR VMWARE VCLOUD ENVIRONMENTS

EMC VNX, VMware vCloud Director, VMware vCenter Chargeback Manager

- Increase Storage Efficiencies
- Meet Service Level Agreements
- Enable Effective and Accurate Billing

EMC Solutions Group

Abstract

This white paper explains how EMC® VNX™ series of unified storage arrays can provide tiered storage solutions to VMware vCloud® Director™.

Part Number H11208

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Executive summary

Business case

VMware vCloud® Director™ gives customers the ability to build secure private clouds that dramatically increase datacenter efficiency and business agility. For existing datacenters, VMware vCloud Director delivers cloud by pooling virtual infrastructure resources and delivering them to users as catalog-based services. End users can consume infrastructure without the burden of manual configuration and provisioning.

Service providers must be capable of accurately meeting service level agreements (SLAs) for a wide variety of tenant organizations and end users, while also making the most efficient use of the resources available. This requires having the ability to provide appropriate resources to meet the tenant needs while controlling the oversubscription of the assigned resources. Accurate and efficient subscription of resources to tenants can be realized by creating multiple tiers of resources, having the tenant access and consume only the resources appropriate to their SLA. All of these requirements must be achieved while maintaining the ability to bill accurately and effectively for the resources consumed.

Resources such as compute (CPU and RAM), storage, and network are fundamental resources for service providers to consider in a vCloud environment. These resources can be grouped into multiple tiers based on their specification, capacity, or performance capabilities.

Storage is a key resource in a VMware® vCloud environment, at both the physical infrastructure level and the Virtual Datacenter (vDC) level. Configuring storage to support a VMware vCloud environment requires considering a wide range of customer use cases, workloads, and virtual machines.

The EMC® VNX™ series of unified storage arrays offers a range of storage features and functionality that can be leveraged in a VMware vCloud environment to provide tiered storage solutions with improved performance, increased scalability, secured separation, and more flexibility for service offerings.

Solution overview

This white paper discusses solutions available to service providers looking to implement storage tiering in their VMware vCloud environments. The solutions discussed in this white paper include:

- Using single disk type storage pools in VMware vCloud Director
- Implementing profile-driven storage in vCloud Director with EMC VNX
- Leveraging EMC VNX Fully Automated Storage Tiering for Virtual Pools(FAST VP)
- Aligning VMware vCenter™ Chargeback Manager™ to storage tiers
- Meeting greater number of SLAs

Key components

The key components discussed in this whitepaper are as follows:

EMC VNX–The EMC VNX platform provides high-end, high-performance, multi-dimensional storage using network-attached storage (NAS) and storage area network (SAN) protocols while providing storage replication for business continuity and disaster recovery solutions. Optimized for virtual environments and applications, EMC VNX provides unsurpassed simplicity and efficiency.

VMware vCloud Director–VMware vCloud Director enables customers to build secure multitenant clouds by pooling infrastructure resources into virtual datacenters and enabling those resources to be consumed by users on-demand.

VMware vCenter Chargeback™ (vChargeback**) Manager**–vChargeback customizes cost models for the processes and policies of different organizations. Integration with VMware vCloud Director enables automated chargeback for cloud environments.

Key benefits

The key benefits of the features discussed in this white paper are:

- Service providers can increase storage efficiencies in their vCloud environments by leveraging FAST VP on EMC VNX.
- EMC VNX platform integrates with and enhances the latest VMware vCloud functionality for profile driven storage.
- A greater number of service offerings can be generated by service providers through a combination of EMC VNX storage and VMware vChargeback Manager.
- EMC VNX family of unified storage arrays, when deployed with VMware vCloud Director and vCenter Chargeback Manager, provide the foundation for increased agility, services, and efficiency in cloud deployments.

Introduction

Purpose

This document is intended to communicate how storage tiering can be achieved in VMware vCloud environments with EMC VNX.

Scope

This document covers configuring storage and billing for storage tiering in VMware vCloud environments with EMC VNX unified storage and VMware vChargeback Manager.

Audience

This white paper is intended for EMC employees, partners, and customers, including IT planners, virtualization architects and administrators, and any others involved in evaluating, acquiring, managing, operating, or designing a cloud infrastructure environment using EMC technologies.

Terminology

This paper includes the following terminology.

Table 1. Terminology

Term	Definition
Storage tiering	Storage tiering is the assignment of data to different types (tiers) of storage media in order to reduce total storage cost.
Fully Automated Storage Tiering for Virtual Pools (FAST VP)	FAST VP operates by periodically relocating the most active data up to the highest performance storage tier. Less active data is relocated to the lower performing storage tiers as appropriate when new data needs to be promoted.
Organization	An organization is the unit of multitenancy that represents a single logical security boundary. An organization contains users, virtual datacenters, and networks.
Provider Virtual Datacenter (PvDC/Provider vDC)	A PvDC is a grouping of compute and storage resources from a single vCenter server instance. A Provider VDC consists of a pool of physical compute resources and one or more datastores. Multiple organizations can share provider VDC resources.
Organization Virtual Datacenter (Org vDC/Organization vDC)	An Org vDC is a subgrouping of compute and storage resources allocated from a Provider VDC and assigned to a single organization. An Org vDC is provisioned resources using vCloud Director resource allocation models.
Resource allocation models	Resource allocation models define how resources are provisioned to an Org vDC from the PvDC. They also define how resources can be used when deploying virtual applications (vApps) within the Organization VDC.

Term	Definition
vApp	A vApp is a container for a distributed software solution and is the standard unit of deployment in vCloud Director. It consists of one or more virtual machines and can be imported or exported as an OVF (open virtualization format)package.
VMware Storage Distributed Resource Scheduler (DRS)	Storage DRS is a feature introduced in vSphere 5.0 providing smart virtual machine placement and load balancing mechanisms based on I/O and space capacity.
FAST Cache	FAST Cache is a storage performance optimization feature that provides immediate access to frequently accessed data by using Flash drives.
Storage pool	A group of disk drives for configuring pool LUNs (thick and thin).
Storage profiles	Storage profiles enable storage capabilities such as RAID level, Thin or Thick Provisioning, replication state, and much more to be made visible within vCenter.
VMware vSphere API for Array Integration (VAAI)	VAAI is a set of APIs that enable offloading specific tasks to storage arrays.
VMware vStorage APIs for Storage Awareness (VASA)	VASA is a set of APIs that enable vCenter to see the capabilities of storage array LUNs and corresponding datastores. VASA forms the basis for the capability in VMware vSphere, called "profile-driven storage".
EMC Virtual Storage Integrator (VSI)	The EMC VSI is a vSphere client plug-in framework to manage EMC storage.
EMC Unisphere	Unisphere is an easy-to-use Web-enabled interface for remote management of EMC VNX platforms, offering an intuitive interface to manage file and block storage.

Enabling storage tiering for vCloud

Overview

VMware vCloud Director pools datacenter resources, including compute, memory, storage, and network, along with their relevant policies, into virtual datacenters. These physical resources are first presented to VMware vCenter, and subsequently to vCloud Director where they are configured as logical datacenters called Provider Virtual Datacenters (Provider vDCs). Tenant organizations in vCloud draw on and consume resources from the Provider vDCs via Organization Virtual Datacenters (Org vDCs). Each Organization vDC within an Organization is a virtual datacenter that can consume resources from a single Provider vDC only. Provider vDCs can provide resources to multiple Org vDCs. It is the individual vApps of the tenant that reside in these Org vDCs.

Figure 1 shows an example of physical resources presented through vSphere to vCloud.

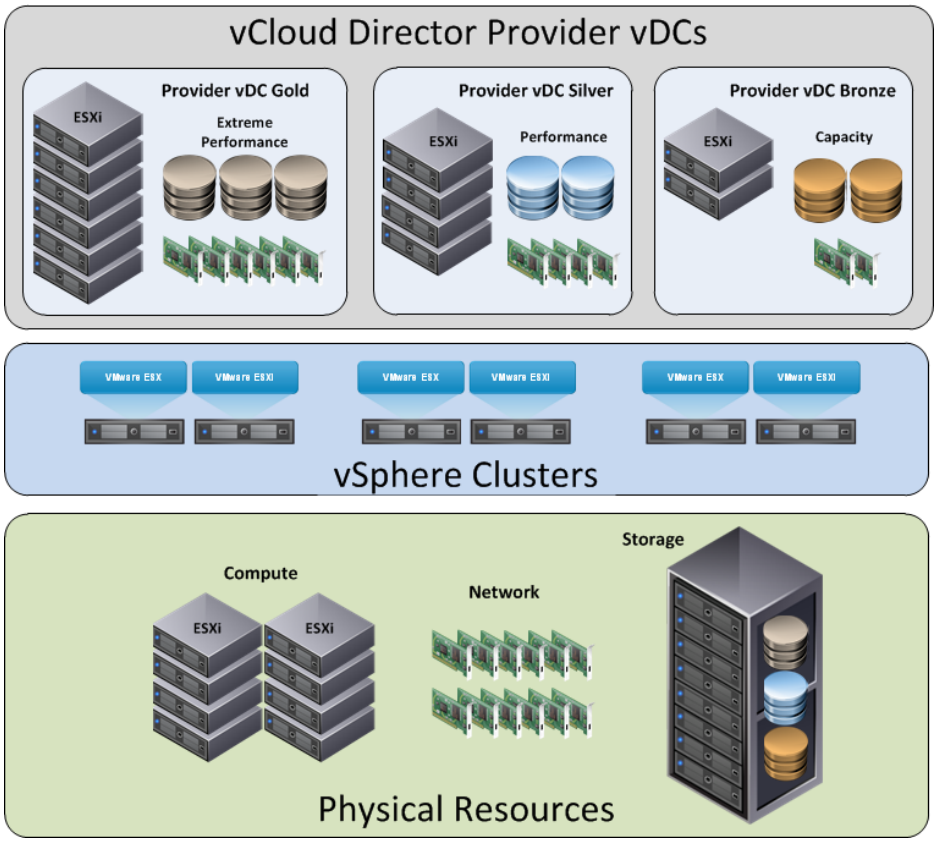

Figure 1. Example of physical resources presented through vSphere to vCloud

Performance requirements vary between vApps. Some vApps require more CPU or memory, while others are more disk intensive and therefore require higher performing storage. Organization vDCs can be categorized by departments or business functions where each contains vApps of different performance requirements. To address these different requirements, Provider vDCs must be configured to offer multiple service levels within vCloud. These service levels are often categorized as precious metals such as Gold, Silver, and Bronze.

Table 2 shows an example of tiered resources in PvDC.

Table 2. Example of tiered resources in Provider vDC

Provider vDC	CPU	Memory	Storage
Gold	Hex Core procs	256 GB	Flash
Silver	Quad Core procs	128 GB	Serial Attached SCSI (SAS)
Bronze	Dual Core procs	64 GB	Near-line SAS (NL-SAS)

Accurately capturing the performance requirements to be satisfied within each service level can be a challenge. While most operating systems and applications have well defined minimum requirements around storage capacity, CPU, and memory resources, it is more difficult to quantify the actual performance requirements of the storage.

The performance requirements for storage can be estimated or measured in different ways. Some tenants will break their requirements down into read and write latencies, sequential or random, or simply ask for a specific number of thousand IOPS. Then there are tenants who judge performance requirements from an application perspective and require resources to satisfy their applications' needs.

Examples may include looking to size storage to support:

- 2000 heavy Exchange users with 1 GB mailboxes.
- An Oracle-based application with a 60:40 Read/Write ratio.
- A data warehousing application with a 100 percent read profile.

Note It is important not to forget about capacity requirements, as sometimes the storage requirement is simply about capacity, not performance.

The storage design challenge within VMware vCD is in providing resources to meet all of the various performance requirements, while also managing sudden surges or spikes in demand for those same resources. The intention for any cloud provider, public or private, should be to allocate resources as efficiently as possible within vCD and then bill accordingly.

Appropriate configuration and allocation of storage resources to vCloud Organization and Provider vDCs is key to enabling and achieving an efficient storage tiering model.

The solutions discussed in this document are based on the revisions of software for each of the primary products listed in Table 3.

Table 3. Primary product version

Product	Software version
VMware vCloud Director	v1.5, v5.1
VMware vSphere™ (ESXi® and vCenter)	v5.0, v5.1
EMC VNX	Block OE 5.32 w/ File v7.1.55.3
VMware vCenter Chargeback Manager	v2.5

EMC VNX

EMC VNX storage arrays allow multiple tiers of storage to be presented to VMware vCloud environments. Traditionally, storage in vCloud environments has been classified into different tiers based on properties such as drive type or RAID type. EMC VNX enhances storage tiering capabilities in vCloud with Virtual Provisioning. EMC VNX Virtual Provisioning provides the flexibility of configuring pool-based storage for vCloud environments, in thin or thick format, spread across multiple RAID protection types and across multiple tiers of disk.

Storage pools can be homogeneous (single drive type) or heterogeneous (different drive types). Heterogeneous pools are the building blocks for data efficiency services like FAST VP, which automatically places the most frequently used data on faster performing drives and places less actively used data on lower performing drives.

VNX Virtual provisioning technology supports features such as hot sparing, proactive sparing, and the ability to migrate data between thin LUNs, thick LUNs, or traditional LUNs without incurring application downtime.

EMC VNX supports three different types of physical disk. FAST VP requires a minimum of two disk types within a storage pool in order to provide tiering. The three possible tiers of storage consist of:

- Extreme performance: Flash drives
- Performance: SAS drives
- Capacity: NL-SAS drives

By enabling each tier within a pool to have its own RAID type, each tier can offer unique advantages in performance and cost. The capacity of each tier can be expanded, in a completely non-disruptive procedure, by simply adding more disks of that drive type. Upon expansion, the storage pool automatically relocates the existing slices of data to redistribute the load across the old and newly available disks for that tier.

Table 4 shows the RAID types for each storage tier.

Table 4. Example of different RAID types per storage tier

Disk type	RAID type	Preferred drive count options
Flash	RAID 5	4+1, 8+1
SAS	RAID 5	4+1, 8+1
NL-SAS	RAID 6	6+2, 14+2

Note RAID 1/0 is also possible.

EMC VNX integration with VMware vStorage API for Array Integration (VAAI) enables vCloud Director to leverage array-based thin provisioning for Block storage. Thin provisioning enables storage overcommit, which is very typical in service provider environments in helping to increase profit margins and on-board more customers. It is recommended to leverage array-based thin provisioning, as cloud workloads are transient in nature.

FAST VP

FAST VP continuously monitors and identifies the activity level of data in storage pools at the sub-LUN level, and periodically moves active slices of data and inactive slices of data to the most appropriate storage tier based on policy—most-active data to the highest performance tier, less-active data to the lowest cost/highest capacity tier.

FAST VP works at a 1 GB granularity. Each 1 GB block of data is referred to as a "slice". FAST VP relocates data by moving the entire slice to the highest available storage tier.

Figure 2 shows the heterogeneous storage pool concept.

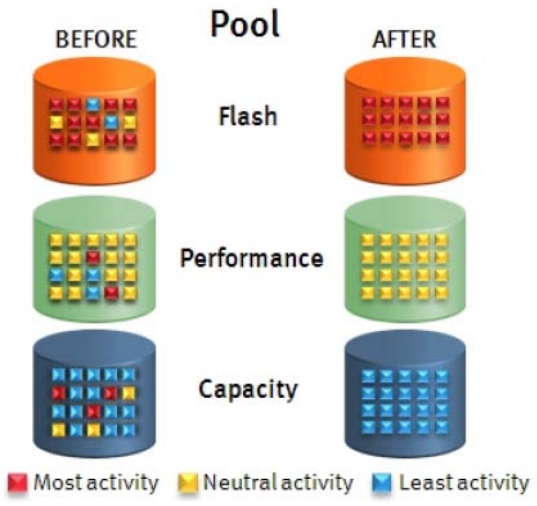

Figure 2. Heterogeneous storage pool concept

Pool performance is maximized by on-going load-balancing within a tier, where FAST VP can analyze and move data within a tier to resolve any imbalance between heavily used and underused disks. Administrators can control and manage the tiering activity by leveraging tiering policies.

FAST Cache

FAST Cache is a storage performance optimization feature that provides immediate access to frequently accessed data. FAST Cache compliments FAST by automatically absorbing unpredicted spikes in application workloads. FAST cache uses enterprise Flash drives to extend existing cache capacities. FAST cache monitors incoming I/O for access frequency and automatically copies frequently accessed data from the back-end drives into the cache.

Availability and protection

High availability should also be considered as part of a service level of storage. Service providers can configure different levels of RAID protection as well as configure different levels of path management within the SAN.

The EMC VNX unified storage family provides five 9s (*99.999* percent) availability, including dual-storage processors, mirrored cache, and redundant data paths, drive connections, and power supplies.

The EMC VNX platform provides a wide range of front-end connectivity protocols as well as a range of RAID protection configurations (RAID 5, RAID 6, and RAID 1/0) across multiple disk types, such as Flash, SAS, and NL-SAS.

EMC PowerPath®/VE enables even higher levels of availability and performance for EMC VNX storage arrays. Installed on the vSphere hypervisor, PowerPath/VE optimizes usage of all available paths between virtual machines and their storage over iSCSI or Fibre Channel, proactively managing the failover of paths in the event of failure, and the restoration of paths when available again so that full availability is automatically restored. Additionally, vCenter Update Manager can remediate the installations of PowerPath/VE against a user-defined baseline to ensure compliance across every instance.

Resource isolation

EMC VNX offers isolation of resources at the storage layer for multitenant environments. Service providers can elect to offer tenants shared storage, dedicated storage, or both. In a shared storage model, storage providers can allow tenants to reside on LUNs configured across shared storage pools. In a dedicated storage model, Service Providers can elect to configure storage pools on a per tenant basis, thus ensuring that tenants are physically isolated from one another by not sharing backend disk spindles. The exact location of the tenants data on the storage array can be specified down to the physical disk or disk array enclosure, ensuring that multitenant data does not reside on common storage resources.

Service providers can achieve isolation of storage resources in vCloud in a number of ways such as:

- Assigning LUNs, storage pools, or RAID groups to specific applications
- Dedicating LUNs, RAID groups, or storage pools to vCloud Director Provider vDCs

The flexibility in implementing any of these configuration strategies enables service providers to eliminate resource contention across tenant applications, while simultaneously ensuring the secure separation of user data.

These combined features of VNX storage arrays provide a great advantage to service provider vCloud environments where performance and capacity requirements are dynamic across a wide range of systems and applications.

VMware vCloud Director

VMware vCloud Director enables service providers and organizations to create logical datacenters that are composed of compute, network, and storage resources, selected from the underlying physical hardware layer. These logical datacenters are referred to as Provider vDCs.

The configuration of Provider vDCs, Organization vDCs, and organizations are primary focal points, so it is worth repeating the more significant configuration rules:

- An organization may have multiple Organization vDCs.
- Each Organization vDC within an organization can consume resources from a single Provider vDC only.
- Provider vDCs can provide resources to multiple Org vDCs as shown in Figure 3.

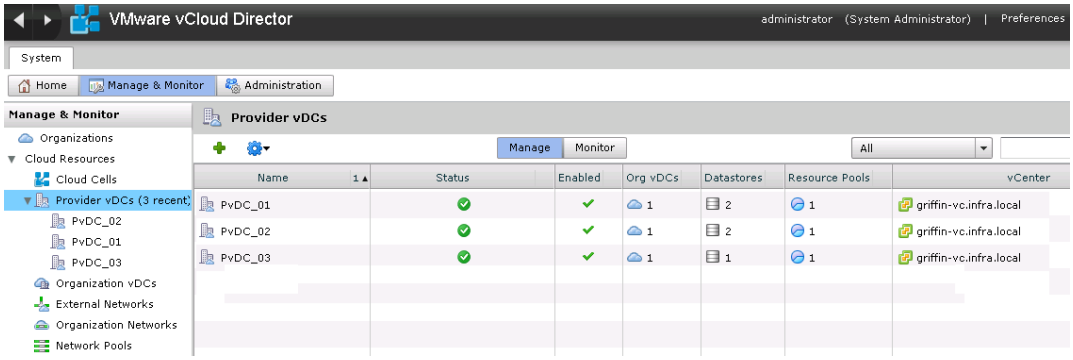

Figure 3. Provider vDC inventory view in vCloud Director v1.5

Provider vDCs in vCD pre-version 5.1, could not distinguish between the storage types of the datastores assigned as resources. In order to avoid indeterminate I/O performance for virtual machines, single type storage was required to be configured in a Provider vDC, meaning that tiering was not possible natively within a Provider vDC.

For a vApp author building a typical multi-tier application requiring gold-tier storage for a database and silver-tier storage for the Web and middleware, this presented a real problem that could not be solved natively within vCloud Director. A third-party solution such as EMC FAST VP would be required to satisfy the tiered storage requirements.

As of vCloud Director v5.1, the underlying storage profiles feature in vSphere is surfaced to the vCloud layer. Storage profiles are used to identify the performance and characteristics of different storage types. The fact that vCD can distinguish the datastore types, as defined at the vSphere, means that different tiers of storage can be assigned and used within a single Provider vDC.

This mix of available storage types natively within the Provider vDC means that a vApp author can deploy their multi-tier application more effectively, deploying various virtual machines on appropriate tiers of storage within the vApp. Refer to Figure 4 for details.

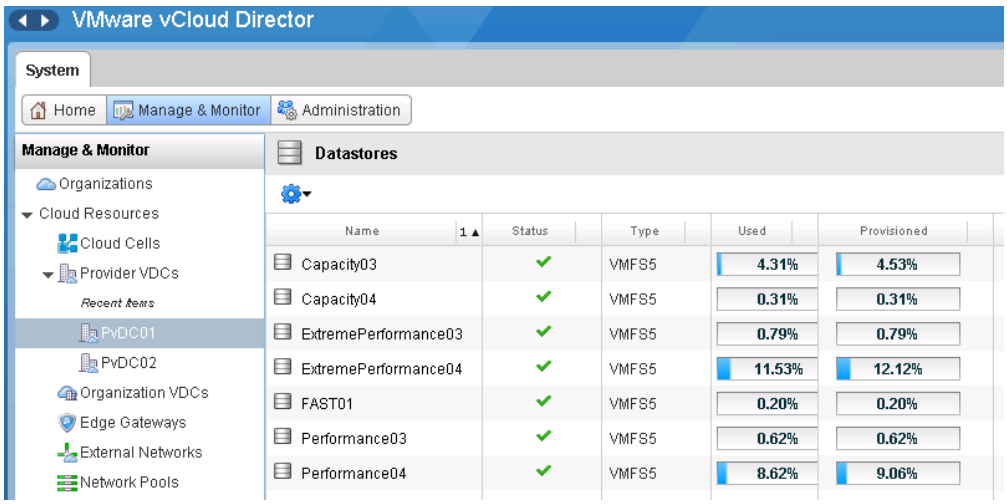

Figure 4. VNX provided multiple tiers of storage for datastores in vCloud v5.1

Storage profiles are also integrated with VMware vSphere Storage vMotion® (Storage vMotion) and VMware vSphere Storage DRS™ (Storage DRS). This enables the automatic relocation of workloads to other datastores within the Provider vDC that match the requirements specified by the storage profile.

The granularity of the storage tiering in vCloud can be enhanced further by leveraging EMC FAST VP, which enables the automatic tiering of the storage at a sub-LUN level. FAST VP operates below the virtual machine and VMWare Virtual Machine Disk Format (VMDK) levels, automatically and transparently moving the slices of data to the most appropriate storage tier. FAST VP is independent of vCloud storage profiles, so it is equally effective with any version of vCD. Refer to Figure 5 for details.

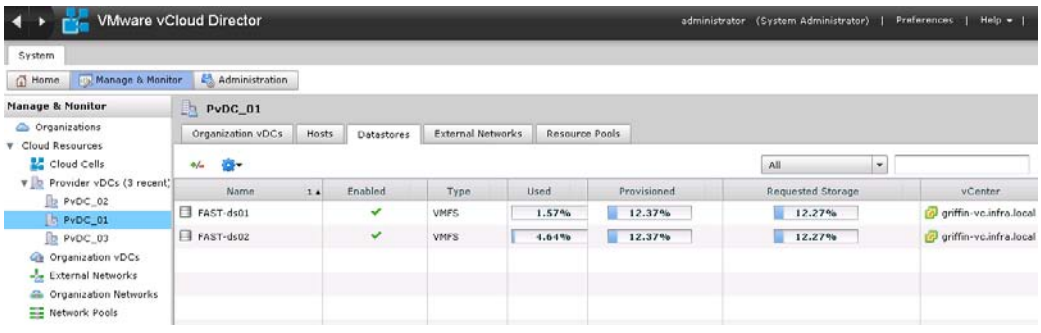

Figure 5. FAST VP enabled datastores in a Provider vDC (PvDC_01) in vCloud v1.5

By leveraging EMC FAST VP, each datastore within a PvDC can be spread across a pool of different storage types. vCD is unaware of the automated tiering capability of the assigned datastore(s), but the key differentiator is that the storage array is intelligent enough to automatically move the appropriate slices of data to the higher tier of disk if the operations on the virtual machine disk require it. Those virtual machines in a vApp that require more performance will have their 'hot' slices of data promoted to the higher performing tier of storage, while the 'cold' or 'less busy' slices of data will remain on the lower tiers. These slices of data are 1 GB in size and are automatically tiered by the EMC FAST VP technology, completely transparent to the applications, systems, and users external to the storage array.

Using this FAST VP technology the EMC VNX platform enables service providers to configure multiple tiers of storage within their vCloud environment, providing automated storage tiering at a more granular level to different tenants and organizations.

Compute and network resources

Storage is only one of the resources required in vCloud environments. Organizations also require CPU and memory resources. Organizations in vCloud environments draw all of their resources from Org vDCs, whose resources are drawn from Provider vDCs. A Provider vDC is a collection of CPU, memory, and storage resources abstracted from vSphere.

Network resources in vCloud Director are built on the networking resources available in vSphere. Networks are not considered to be part of Provider vDCs, but vCloud Director reports which external networks are available to the cloud structures that use the Provider vDC. Different service levels of network resources can be implemented at the networking infrastructure layer.

Appropriate allocation of required CPU, memory, and network resources is just as important as storage to the successful operation of Provider vDCs in vCloud environments. Just as Provider vDCs allow you to pool infrastructure resources to create standard offerings, Provider vDCs can also be grouped into different levels of compute resources to compliment different tiers of storage resources. For example, best of breed compute, memory, and network resources can be combined with the fastest storage resources to create a Gold Provider vDC, which can then be priced higher for consumers than Silver or Bronze Provider vDCs.

VMware vCenter Chargeback Manager

Creating any chargeback solution in a cloud environment requires flexible metering and costing models that can account for the utilization of all resources within a multitenant environment. VMware vCenter Chargeback Manager, as shown in Figure 6, is an end-to-end, cost-reporting solution for virtual environments that leverages vSphere and vCloud Director.

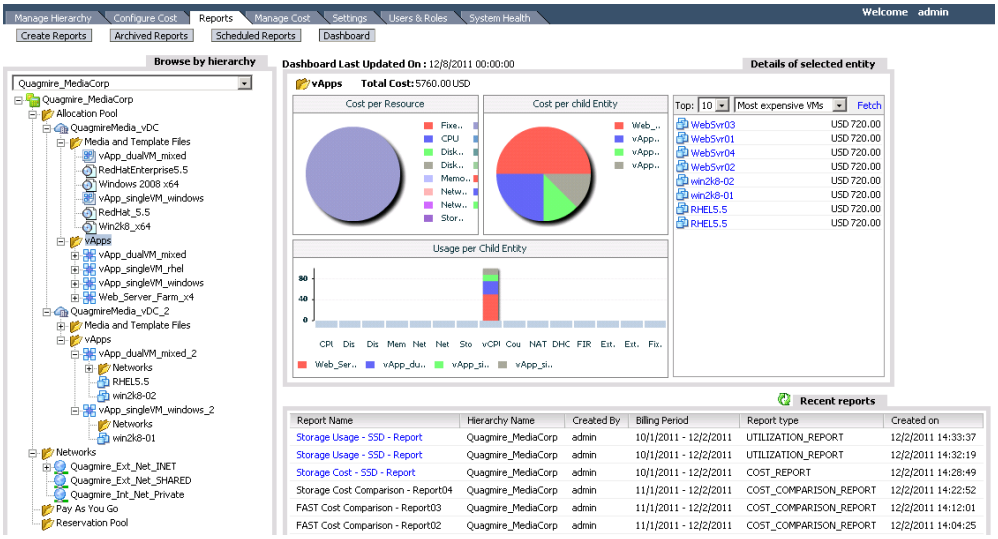

Figure 6. vChargeback manager dashboard view

VMware vChargeback and vCloud Director can take advantage of EMC VNX storage tiering to enable the application of different cost models for different levels or tiers of storage.

In a simple model, a service provider can opt to use only FAST-enabled storage for all vApps in an organization. In such a configuration, a single flat rate can be applied to the storage where the storage array maximizes the efficiency of the storage used.

Alternatively, service providers can leverage separate storage pools of different storage type, such as Flash, SAS, and NL-SAS. Having the ability to create entity-specific reports with different cost models means that service providers can run Chargeback reports at the vApp level, with a specific cost related to the tier of storage available to and consumed by that vApp. Refer to Figure 7 for more details.

Allocation Model	Cost Model	Billing Policy
Allocation Pool	VMware Cloud Director Allocation Pool Cost Model	VMware Cloud Director Billing Policy - Allocation Pool
Networks	VMware Cloud Director Networks Cost Model	VMware Cloud Director Billing Policy - Networks
Pay-As-You-Go	VMware Cloud Director Pay As You Go - Fixed Charging Cost Model	VMware Cloud Director Billing Policy - Pay As You Go Fixed Charging
Pay-As-You-Go	VMware Cloud Director Pay As You Go - Resource Based Charging Cost Model	VMware Cloud Director Billing Policy - Pay As You Go Resource Based Charging
Reservation Pool	VMware Cloud Director Reservation Pool Cost Model	VMware Cloud Director Billing Policy - Reservation Pool

Figure 7. Allocation and cost models with billing policies for vCloud Director

Each Organization vDC is configured with a single allocation model that defines how resources are allocated from the Provider vDC. An Organization vDC must be configured with one of the following three allocation models:

- Pay-as-you-go
- Allocation-pool
- Reservation-pool

Costs can be configured on individual Organization vDCs, vApps, virtual machines, media and template files, and networks within an organization. Different rate factors and fixed costs can be set for each of the resources at these levels for a selected cost model. This enables charging for different entities in multiple ways using a single cost model.

More detailed information on resource allocation models can be found at: VMware vCloud Director Resource Allocation Models.

Integration with existing billing systems

Service providers with existing billing systems can directly leverage vCenter Chargeback reports. The report data can be exported in RTF, PDF, and CSV formats and fed directly into any larger or existing billing system. The vCenter Chargeback Manager API can be leveraged for automating all Chargeback-related tasks including the export of report data.

Manual tiering versus automatic tiering

Overview

As EMC storage offers a wide variety of storage types and tiers, service providers can choose to configure individual pools of single-type storage or configure FAST-enabled pools of mixed storage type that can automatically tier the data.

Storage tiering can be accomplished by a number of approaches, including:

- Manual tiering (where every storage pool has only one disk type)
- Automated tiering (where every storage pool has the same mix of disk types)
- Hybrid tiering (where each storage pool has a mix of disk types, but in different ratios)

This decision of how to best configure and allocate the storage tiers can be influenced by factors such as:

- The Chargeback model
- Storage administration

With many pools of single-type storage, a service provider can apply individual cost models appropriate to the storage type of each pool. This model enables the granular billing of storage resources assigned to and consumed by the tenant specific to the static storage type.

With FAST-enabled pools of storage, a service provider can apply a single cost model while trusting the storage array to manage the tiering of the data on the backend across multiple storage types. This model is less granular for billing purposes but is an efficient and flexible model to implement and manage. Refer to Figure 8 for more details.

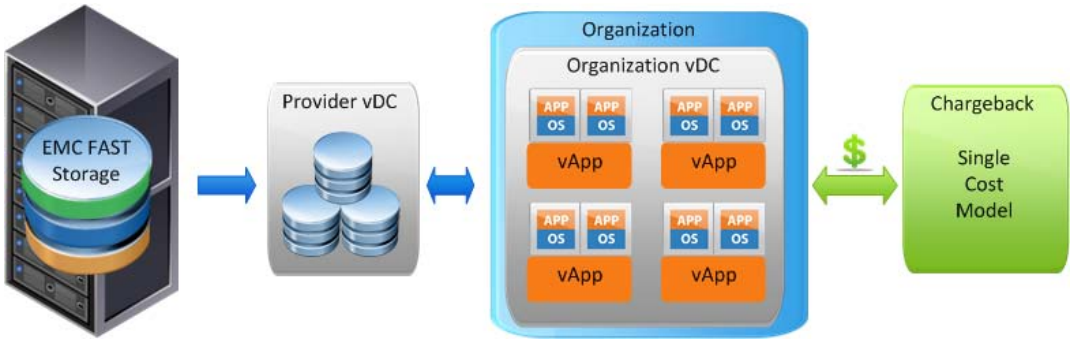

Figure 8. Example of a single cost model applicable to FAST-enabled storage

Homogenous storage pools – Manual tiering

The use of storage pools of single disk type allows service providers to utilize multiple storage pools, each containing a single disk type to support Provider vDCs in vCloud Director. These storage pools are described as homogenous pools, which are of a single disk type and are intended for applications with similar performance requirements. Homogenous pools can be composed exclusively of Flash, SAS, or NL-SAS drives, resulting in all storage devices from any one pool being of identical performance characteristics.

On pre-vCD v5.1 systems, tiering with this approach requires configuring multiple PvDCs, each containing a unique, single storage type. The PvDC resources are consumed by an Organization vDC that can be one of many owned by an Organization in vCD (Figure 9).

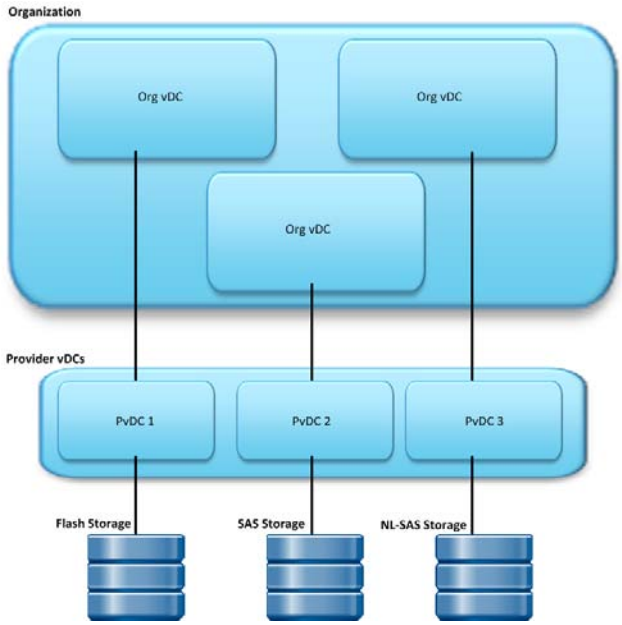

Figure 9. Pre-5.1 multiple storage pools supporting vCD organization with multiple Org vDCs

The multiple Org vDCs within an organization can support different business units or functions, such as engineering, production, or test/dev. Each of these business units may have different performance requirements, so the vCD administrator can map the Org vDC to the appropriate PvDC based on their requirements. For example, the production systems can reside on Tier-0 (Flash) storage, while the Engineering and Test/Dev departments may utilize SAS (Tier-1) and NL-SAS (Tier-2) storage respectively. In this way, the vCD administrator can manually tier the storage.

For each of the Org vDCs illustrated in Figure 9, the vApps and associated virtual machines deployed will be based on the single storage type supporting that Org vDC (via its Provider vDC).

Using this design strategy the vCD administrator can take advantage of the multiple tiers of storage offered by EMC storage arrays. Different tiers of storage can easily be mapped to vChargeback cost models, which can be configured to reflect the level of storage being offered and consumed within the organization.

On vCD v5.1 systems, a single type of storage can be leveraged with profile driven storage to enable multiple tiers of storage within a Provider vDC. The individual storage devices within the Provider vDC can be assigned storage profiles to reflect their performance capabilities. The profiles can be categorized as Gold, Silver, and Bronze, where, in Figure 10, those profiles are reflective of Flash, SAS, and NL-SAS storage respectively.

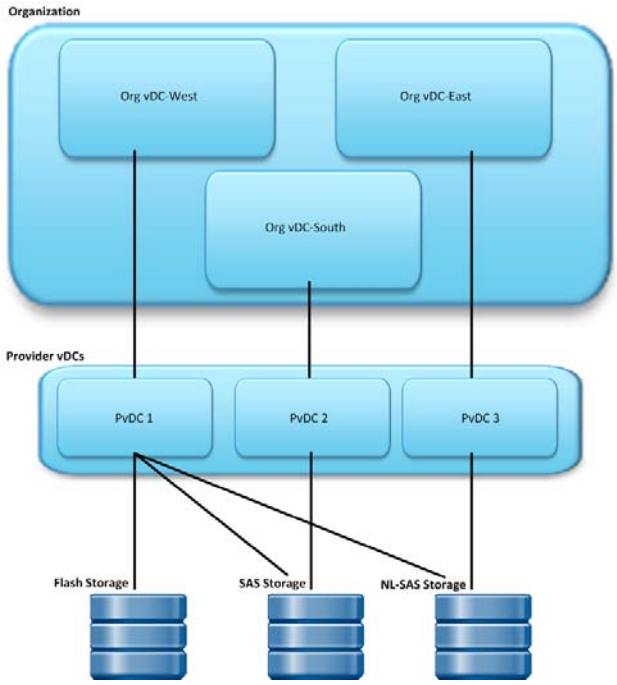

Figure 10. vCD 5.1 Provider vDC with mixed storage types

The storage profiles, which are configured at the vSphere layer before being imported into vCD at the Provider vDC level, can be manually assigned by the vSphere/vCloud administrator or automatically classified by the VMware vStorage APIs for Storage Awareness (VASA) client native to the EMC VNX. Virtual machines, which are tagged or associated with a specific storage profile that will automatically be deployed on a compliant storage device or datastore.

For Org vDC-West illustrated in Figure 10, the virtual machines within the vApp can be deployed on a choice of storage type, unlike Org vDC-South and Org vDC-East, each of which has to deploy all virtual machines in all vApps on a single storage type.

By leveraging the storage profiles feature in vCD 5.1, multi-tiered applications can be deployed on multiple tiers of storage within a single Provider vDC.

More in-depth information on this can be found in the Creating Homogenous Storage Tiers for VMware vCD – Pre vCD v5.1 section.

FAST VP heterogeneous storage pools

FAST VP allows the vCD administrator to leverage the storage tiering abilities of the storage array. FAST VP operates in heterogeneous pools, which are pools consisting of different drive types (Flash, SAS, and NL-SAS).

A vCD administrator working within the confines of the Provider vDC architecture is limited in its ability to provide multiple tiers of storage within a Provider vDC. No tiering is possible in PvDC pre-vCD v5.1. With vCD v5.1, the tiering possible within the PvDC is manual and limited to the virtual machine level; that is, all virtual machine disks must reside on the same tier. EMC FAST VP enables automatic storage tiering at a more granular level by operating below both the virtual machine and VMDK level, tiering the data in 1 GB slices. It is the storage array rather than vCloud Director that is providing the tiering. The storage array is responsible for managing the data placement; that is, locating the data in the appropriate location where the vApps receive the performance required. It is important to note that vCD is unaware of the tiering operations on the back-end storage array.

Figure 11 shows how storage tiering can be achieved based on a single FAST VP storage type.

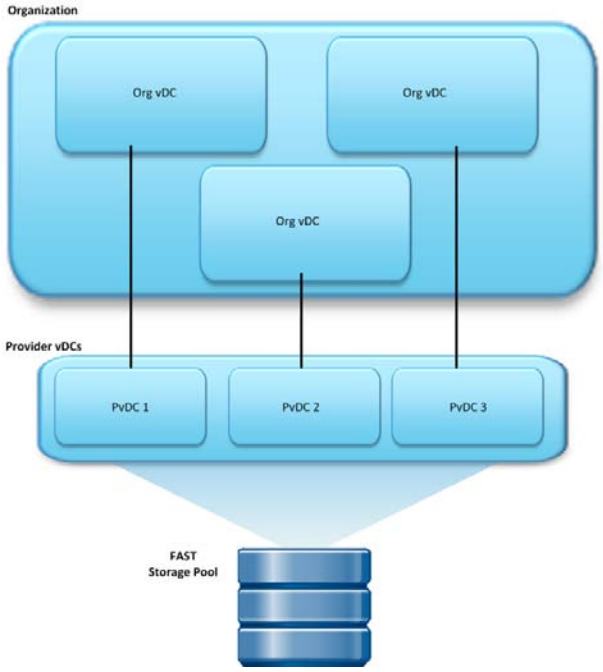

Figure 11. Single FAST pool supporting vCD organization with multiple Org vDCs

The vApps and associated virtual machines operating in vCD that require the higher disk performance will have their data located on the faster disks within the pool, while the less disk-intensive vApps and virtual machines will have their data placed on the slower performing disks. Although vCD has no control over the dynamic placement of the vApps data, the fact that the underlying storage in the Provider vDC is FAST-enabled means that the appropriate tiering is applied by the storage array at the backend.

If required, the capacity of each of the tiers within the FAST pool can be expanded by adding more disks to the storage pool, which will then rebalance the existing data across the newly added disks.

If the service provider requires changing the disk type or service level for a tenant or vApp at any stage, VNX virtual LUN migration can be leveraged to nondisruptively migrate an entire LUN from one storage tier to another across storage pools, for example, from a FAST-backed multi-tiered LUN to a LUN in a static SAS tier. This migration is performed on the storage array where, by persisting all of the relevant properties of the original LUN, the operation is completely transparent to any host or application. Therefore vCD is unaffected by any virtual LUN migration operations.

For chargeback purposes, VMware Chargeback can use a single cost model that is applicable to all storage operations based on FAST-backed storage devices.

Hybrid tiering

A hybrid option can be used to configure multiple FAST pools, each with a different balance of drives types. This concept is illustrated in Figure 12. By having different ratios of drive types in each pool, some pools are weighted in favour of capacity and other pools are weighted for overall performance, while still providing the efficiencies of FAST VP. This enables service providers to charge different prices per tier but maintain the management benefits of FAST pools.

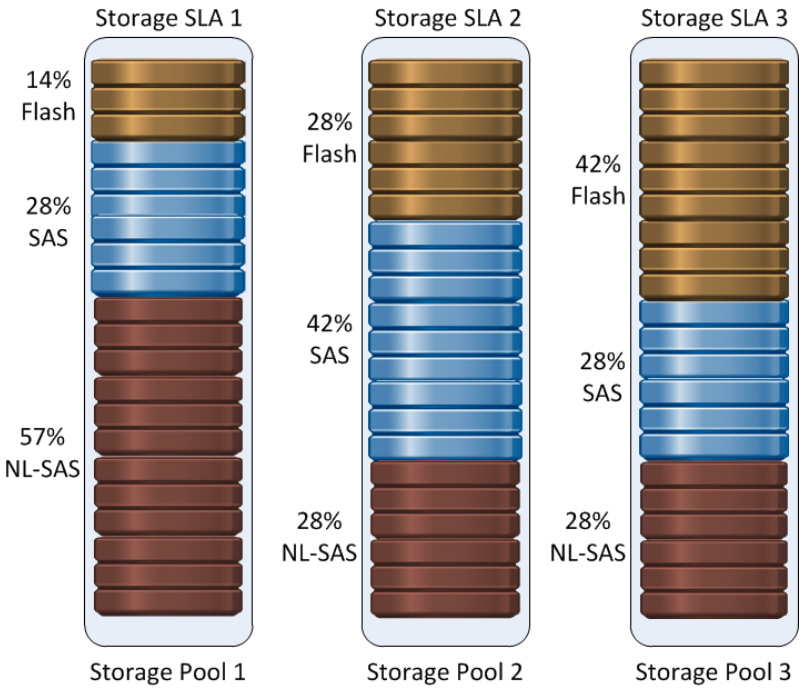

Figure 12. Storage SLAs defined by ratio of disk types in FAST VP storage pools

VMware vCenter Chargeback Manager can apply appropriate cost models and rate factors to suit the service level offered by each of the FAST VP enabled storage pools. Each storage pool can provide automatic tiering, but each pool also offers a considerably different service level based on its capabilities. These different FAST VP storage pools can be categorized and applied to vCloud Director Provider vDCs to address different service levels.

More in-depth information on this can be found in the Configuring FAST-enabled storage for VMware vCD section.

FAST Cache

The use of LUNs backed by FAST Cache is another option when considering the performance capabilities of storage within a PvDC.

One of the major benefits of using FAST Cache is the improved application performance, especially for workloads with frequent and unpredictable large increases in the I/O activity. FAST Cache enables applications to deliver consistent performance by absorbing heavy read/write loads at Flash drive speeds. Refer to Figure 13 for an overview of FAST Cache operations.

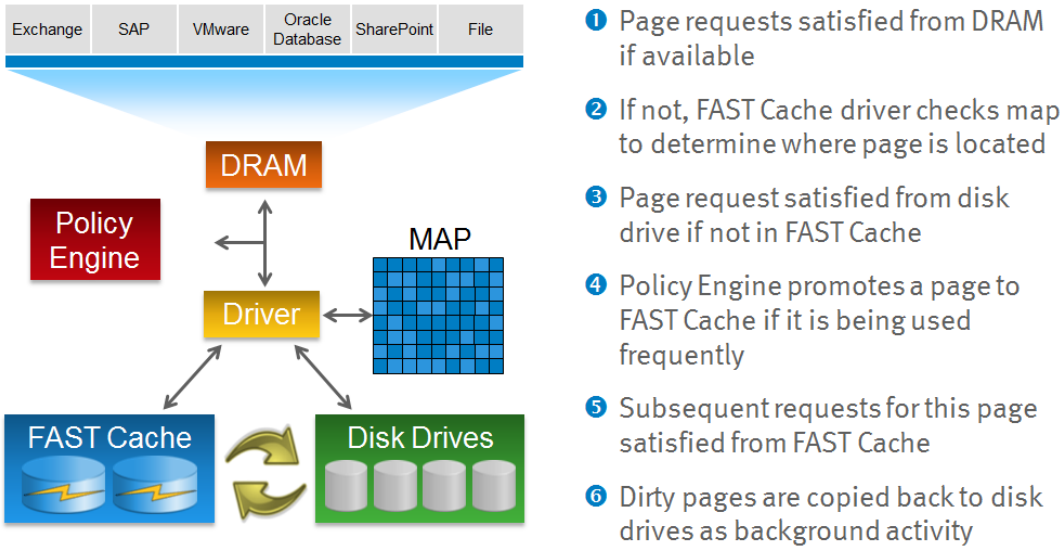

Figure 13. Overview of FAST Cache operations

The section(s) of an application's working dataset that is frequently accessed is copied to the FAST Cache, so the application receives an immediate performance boost by not having to go the longer route to disk for the data, instead having the data provided by the Flash based FAST Cache.

These LUNs that use FAST Cache, presented to vCD via vSphere, are managed identically to any other storage in vCD. These LUNs are configured specifically on the back-end storage array to utilize FAST Cache.

Figure 14 provides a view of how FAST VP and FAST Cache can be leveraged in vCD

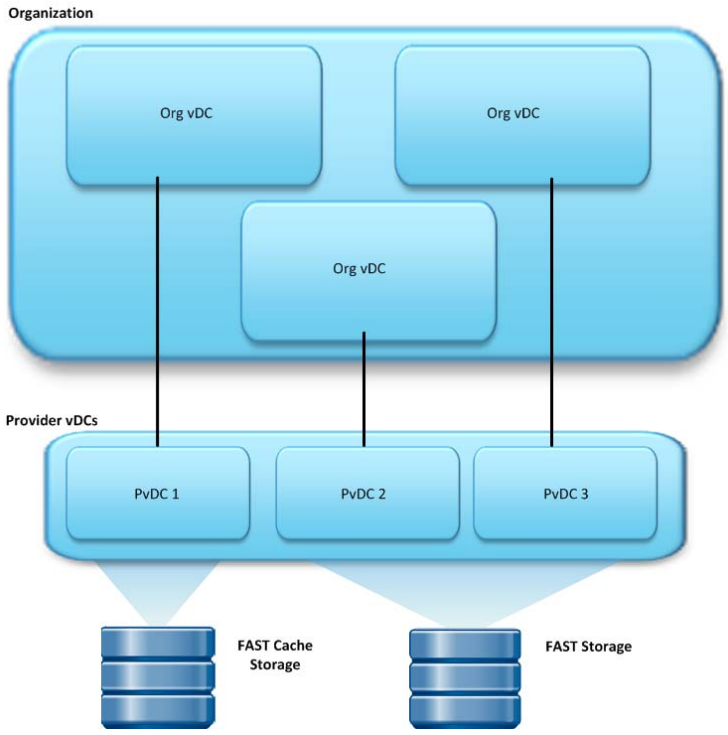

Figure 14. FAST and FAST Cache enabled storage supporting single vCD organization with multiple Org vDCs

Using a separate storage pool of FAST Cache-enabled LUNs enables service providers to maximize the performance and efficiency of the FAST VP and FAST Cache technologies. It is worth considering that not every organization, application, or vApp will require the performance improvements offered by implementing FAST Cache so it may be a more efficient use of the feature to only use it where required.

How-to examples

Configuring FAST-enabled storage for VMware vCD

Before being able to place vApps and virtual machines on the storage, VMware vCloud Director is presented with FAST-enabled storage at the vSphere layer. There are only a few steps required:

- Create the storage
- Assign storage to vSphere
- Configure and format the storage in vSphere
- Assign storage to vCloud Director

The process for configuring this storage begins on the storage array. The storage administrator must first create a storage pool on the VNX. This storage pool must contain different tiers of disk types in order to tier the blocks of data. Refer to Figure 15 for more details.

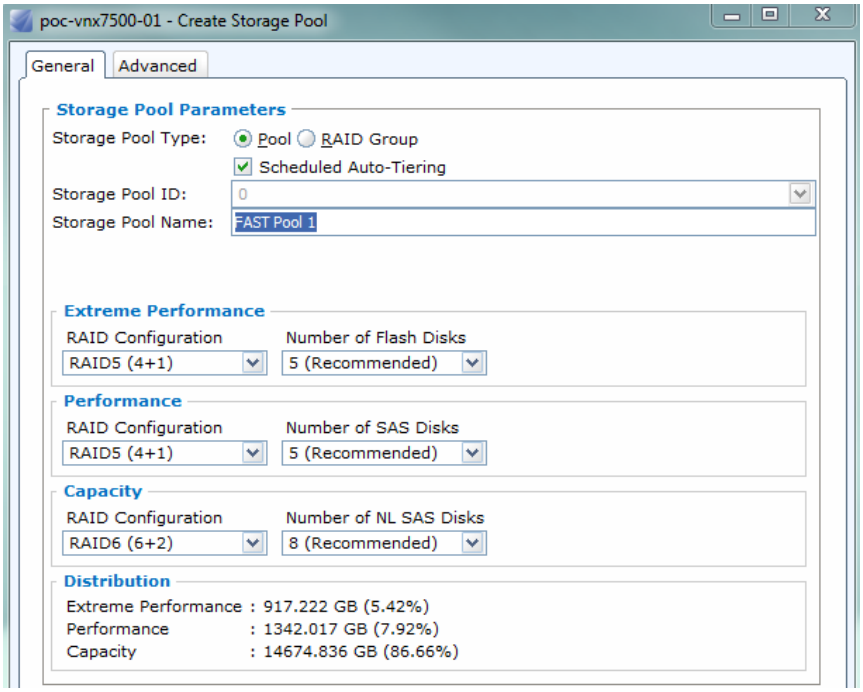

Figure 15. FAST VP: Creating storage pool on VNX

Figure 15 displays the Create Storage Pool view in Unisphere where the user can assign different disk types to support the FAST VP (all operations are also possible via CLI). This particular example demonstrates how a storage pool can be configured with three different storage tiers where Flash, SAS, and NL-SAS disks provide tiers of Extreme Performance, Performance, and Capacity respectively. The majority, 87 percent, of the storage capacity of the storage pool consists of NL-SAS disks for the Capacity tier. The Performance Tier constitutes 8 percent of total storage in the pool, while the Extreme Performance tier on Flash disk accounts for just over 5 percent of the available storage capacity for the storage pool.

In order to create FAST VP pools that meet different SLAs, as mentioned earlier in this white paper, the creation process as displayed in Figure 15 is adapted to assign more or less disks as appropriate to each tier, thereby giving the FAST pool different capabilities around capacity and performance.

Figure 16 illustrates how a pool LUN of mixed RAID type can be created within EMC Unisphere.

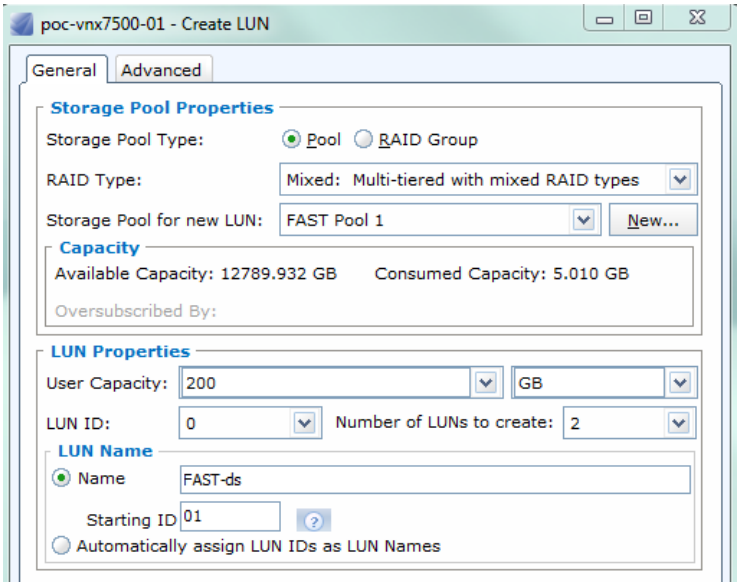

Figure 16. Creating Pool LUN with mixed RAID type

The initial placement of the data can be specified in the tiering policy when creating the LUN(s) that will reside within the storage pool. The storage administrator may choose, on creation, how the LUN should be configured across the available tiers of the storage pool. The default policy setting dictates that the LUN will be configured on the highest available tier of disk and then be auto-tiered from then onwards. Refer to Figure 17 for details.

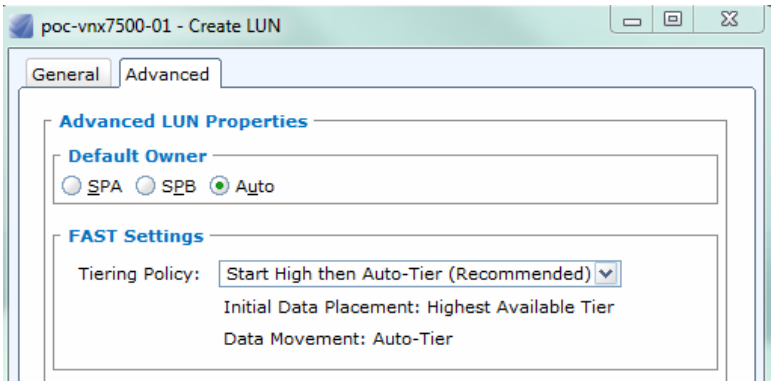

Figure 17. Creating LUN: FAST policy to specify initial placement of LUN in pool

Alternatively the storage administrator may choose a tiering policy that specifies that the LUN, on creation, to be balanced across all storage tiers, or to be located in its entirety on the highest or the lowest available tiers. Refer to Figure 18 for details.

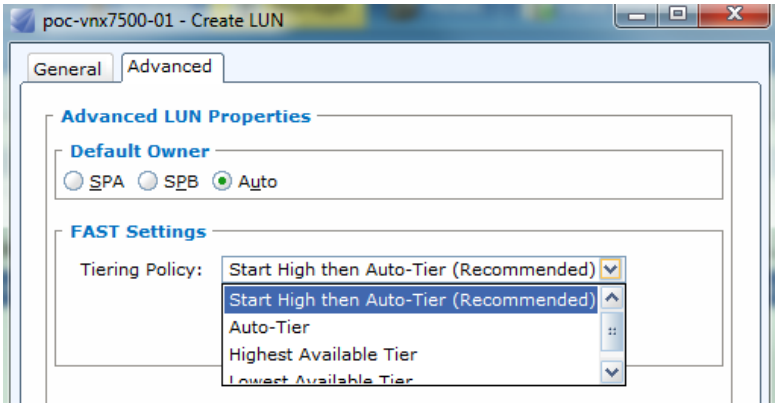

Figure 18. Creating LUN: Additional FAST policy options

The nature of FAST is to promote all data to the highest available storage tier so that the maximum performance and efficiency is being utilized at all times. If required, it is possible to disable auto-tiering on a specific LUN and instead pin the LUN to the appropriate storage tier.

As shown in Figure 19, all other LUN creation options are displayed in the General tab where the LUN size and Thin or Thick properties can be configured. The data as it exists on the LUN will not move or be relocated until a relocation operation executes.

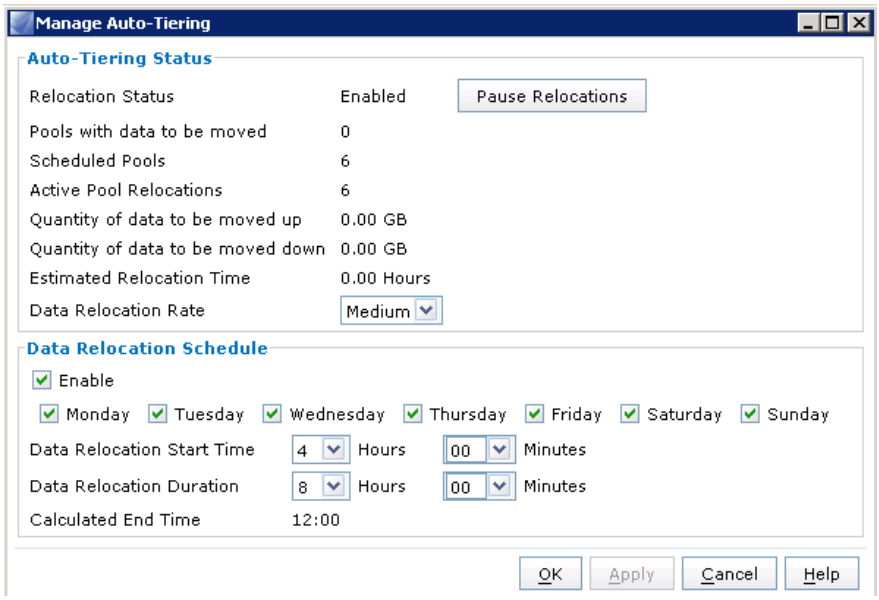

Figure 19. FAST data relocation scheduling

The schedule of the relocation operation can be automated or manually executed. The relocation schedule can be enabled to automatically execute by days of the week and the time of day. The duration and relocation rate can also be set in order to control data relocation operations on the array.

As shown in Figure 20, the amount of data to be relocated within a storage pool is displayed in EMC Unisphere. The relocation information displayed informs the user of the amount of data to be relocated up (promoted) as well as down (demoted). The promotion and demotion of slices of data across the storage tiers is based on how active or 'hot' the slices of data are.

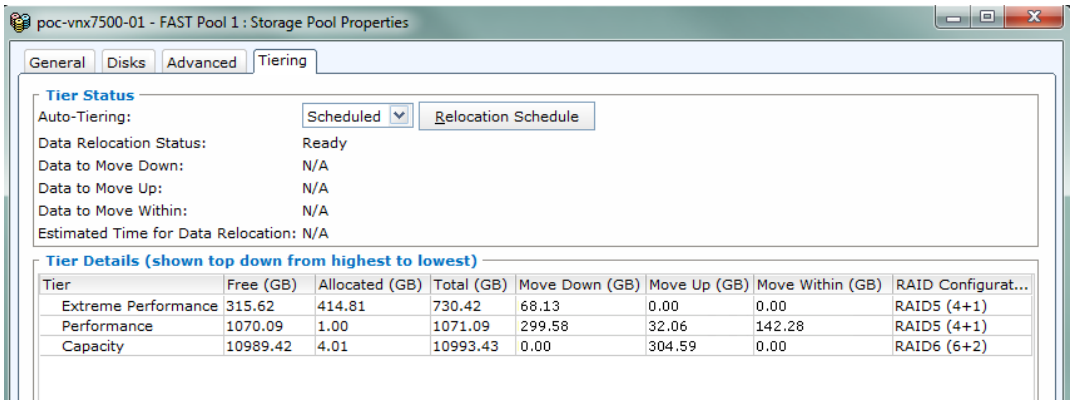

Figure 20. Storage Pool Tiering information

As shown in Figure 21, the relocation of data can be executed manually if the relocation operation is required outside of the schedule. The storage administrator can execute this simply by right-clicking the storage pool, navigating to the Storage Tiering option, and selecting 'Start Data Relocation'.

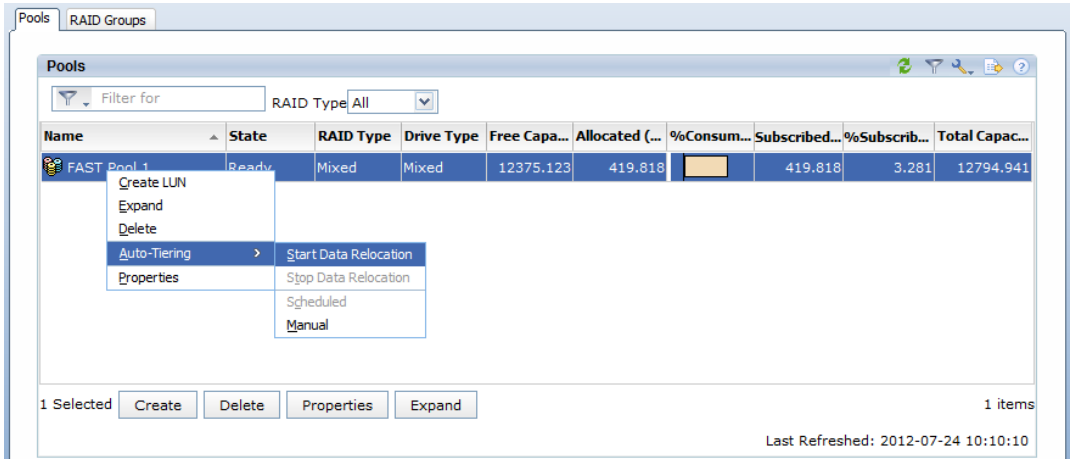

Figure 21. Manual execution of data relocation in FAST Storage Pool

Neither VMware vSphere nor vCloud Director is aware of tiering operations within a LUN, as the tiering functionality is managed at the array level.

The LUN(s) are presented to VMware vSphere in the same way as any other LUN. The LUNs are masked to the ESXi cluster and formatted as Virtual Machine File System (VMFS) datastores shown in Figure 22.

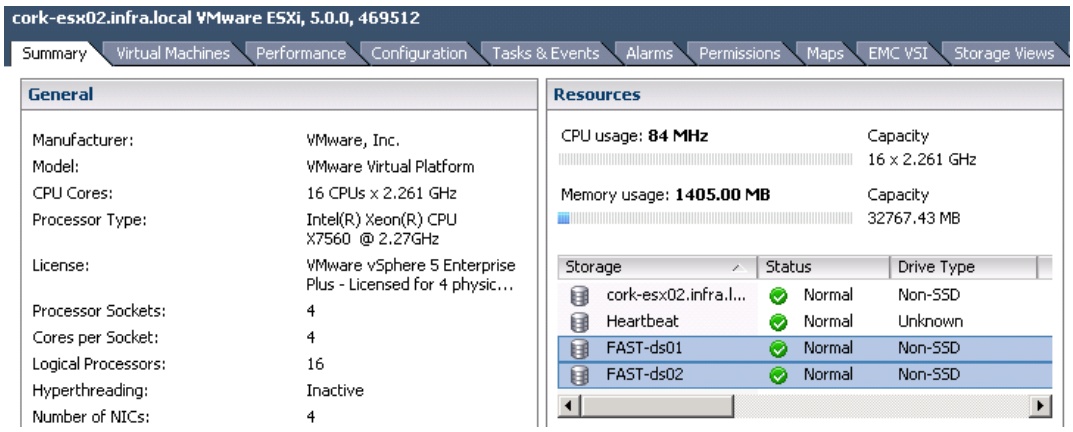

Figure 22. FAST VP LUNs formatted as VMFS Datastores in vSphere

After the ESXi hosts are a managed resource within a Provider vDC in vCloud Director, the managed datastores are then available to be selected and imported as storage resources for a Provider vDC shown in Figure 23.

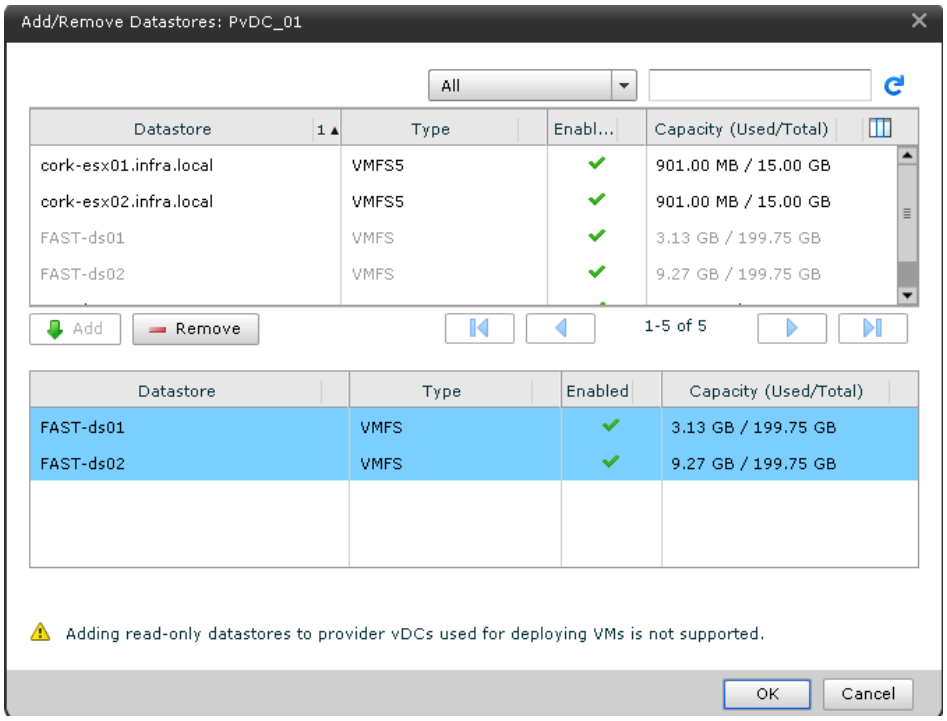

Figure 23. Adding datastore resources to Provider vDC

The result of this configuration is that storage tiering is available for all of the Organization vDCs that consume storage resources from the Provider vDC that contains FAST-enabled storage. Refer to Figure 24 for details.

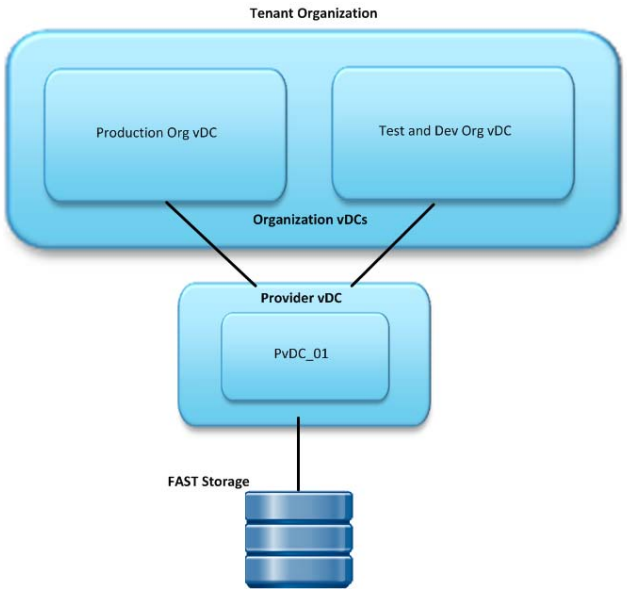

Figure 24. Single vCloud organization with multiple Org vDCs with single FAST pool

VMware vCD, being unaware of these tiering operations on the backend, continues to place vApps on datastores as before while VNX FAST VP manages the tiering on the backend.

Figure 25 shows where base rates can be applied in a Cost Model in vChargeback to align with FAST VP storage being consumed in vCD.

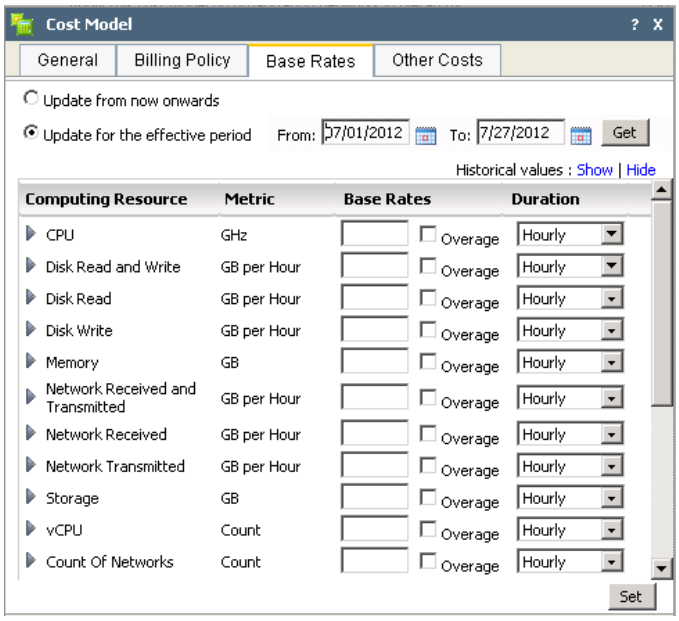

Figure 25. Configuring base rates for FAST storage utilization in vCloud

This storage provisioning model, leveraging the tiering capabilities of EMC VNX FAST VP, enables a single cost model to be created in VMware Chargeback Manager to track and charge for the consumption of FAST VP enabled storage in the vCloud environment.

Creating homogenous storage tiers for VMware vCD – pre vCD v5.1

The use of multiple homogenous storage pools allows service providers the flexibility to manually configure multiple storage tiers to support vCloud Director. These homogenous pools can be composed of Flash, SAS, or NL-SAS drives.

In a scenario, pre vCD v5.1, where two separate tiers of storage are required to support two separate Provider vDCs within vCD, the storage administrator can create the following for example:

- Extreme Performance (Flash)
- Performance (SAS)

The Extreme Performance tier, to be used by the production Org vDC to support the tenant's production systems, is composed of eight Flash disks configured in a RAID 1/0 storage pool as shown in Figure 26.

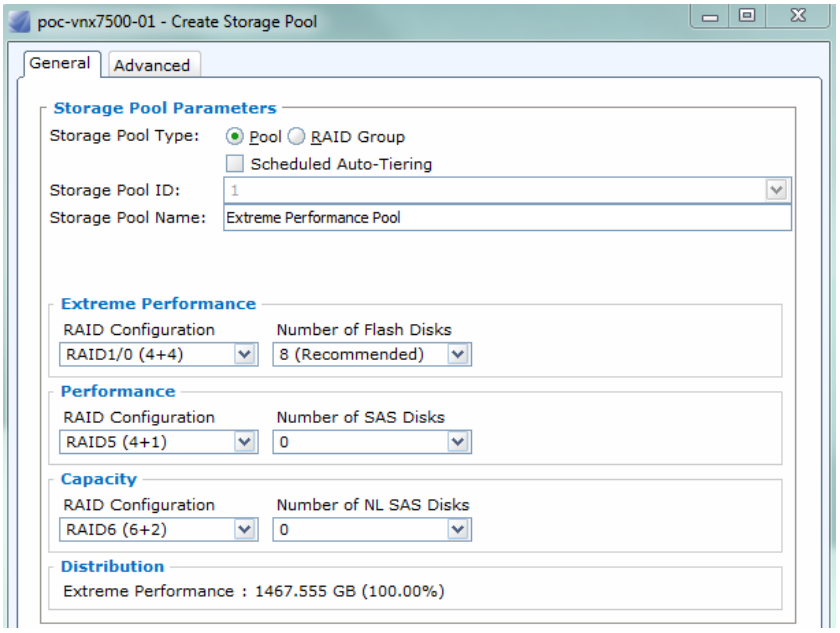

Figure 26. Extreme Performance storage pool creation

This storage pool is created using the same process as creating a FAST-enabled storage pool, but in this case the pool contains only a single disk type and a single RAID type. The amount of disks supporting the storage pool as well as the RAID type of the storage pool can be configured as appropriate based on performance requirements and calculations. Unisphere will specify recommended disk configurations for each tier of disk type.

The same creation process is used again to create a second storage pool, called the Performance pool. This Performance tier can be used by the test and development Org vDC to support the tenant's test and development systems. With RAID 5 protection, this tier consists of SAS disks only and is configured with nine disks.

As shown in Figure 27, the storage pool inventory within EMC Unisphere displays the properties of the newly created storage pools. Properties include the capacity, drive type, space allocated, and consumed figures. Also note that Unisphere indicates whether FAST Cache is being used with this storage pool. In this example, FAST Cache has been enabled for the Extreme Performance pool but is disabled for the Performance pool.

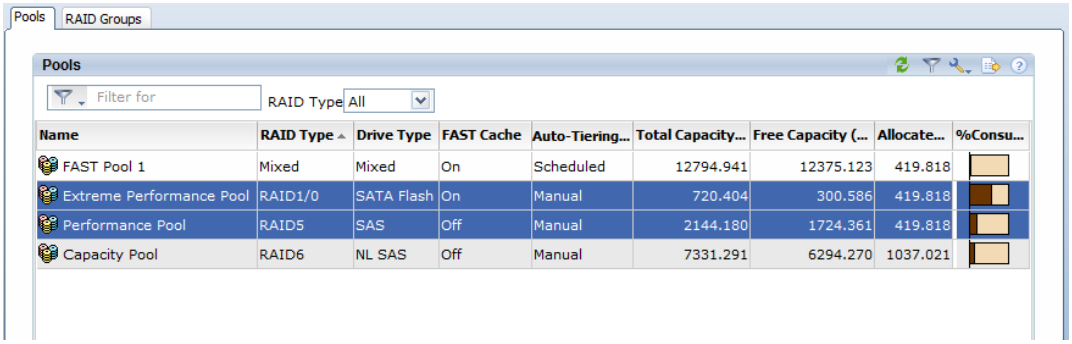

Figure 27. VNX Storage Pool Inventory in Unisphere

FAST Cache can easily be turned on or off within the properties of the storage pool, as displayed in Figure 28.

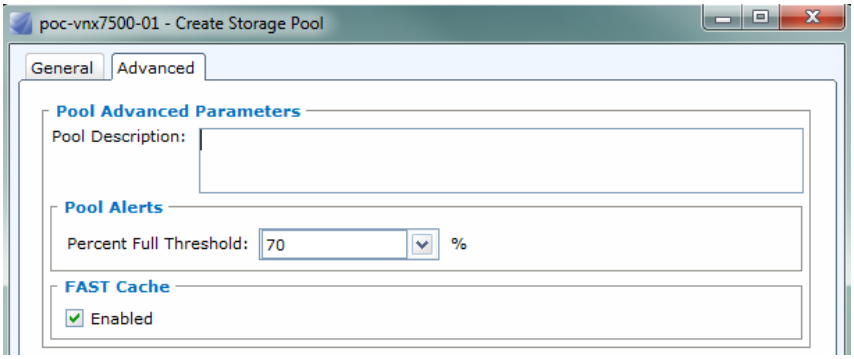

Figure 28. Enabling FAST Cache on VNX Storage Pool

The process for creating LUNs within these homogenous, single disk type storage pools is the same as covered in the previous example of FAST-enabled pools. The storage administrator simply specifies the desired LUN size and whether the LUN is to be thin or thick.

Pre v5.1, VMware vCloud Director assumes and requires that each datastore is of a single disk type and that each datastore in the cluster managed by the Provider vDC has equal and identical performance capabilities.

After the LUNs have been configured in each of the storage pools, they are available to mask to the ESXi server(s), formatted as VMFS datastores, and subsequently be imported into their respective vCloud Provider vDCs as before, as shown in Figure 29.

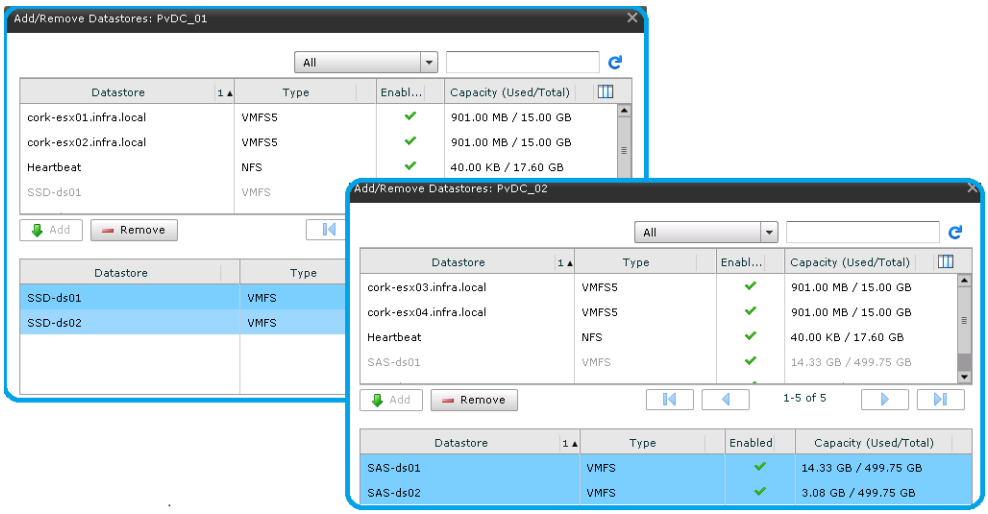

Figure 29. Importing Flash and SAS datastores into separate Provider vDCs

The vCloud environment now contains two Provider vDCs offering different tiers of storage. The Extreme Performance tier, in the shape of Flash-based (SSD) storage with FAST Cache, is available to the production Org vDC via PvDC_01, while PvDC_02 offers the Performance tier of storage to its consumers within the test and development Org vDC.

Figure 30 illustrates how two different tiers of storage can be manually configured in vCD.

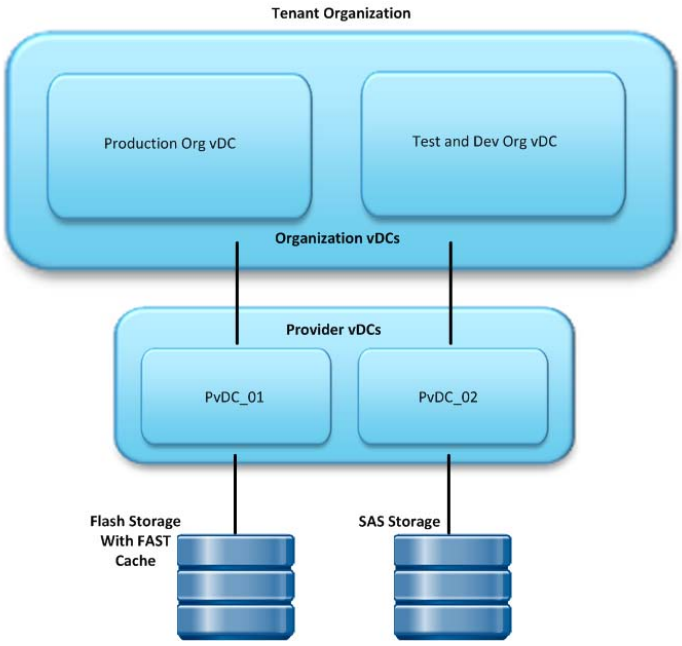

Figure 30. Manual storage tiering within a single organization

Individual cost models and rate factors, specific to each storage tier, can be created and applied in vCenter Chargeback Manager to accurately charge for the utilization of the storage resources by the various vCloud entities within an organization in vCloud.

Creating homogenous storage tiers for VMware vCD – with vCD v5.1 and storage profiles

Using a similar situation to the example detailed previously, multiple homogenous storage pools on EMC VNX can be leveraged in association with VMware's profile driven storage to provide multiple tiers of storage within a single Provider vDC. This is achieved via storage profiles, set at the vSphere layer, which are then exposed to vCloud Director v5.1.

For example, three separate tiers of storage can be configured to support a single Provider vDC, where the storage administrator can create the following tiers:

- Extreme Performance (Flash)
- Performance (SAS)
- Capacity (NL-SAS)

The Extreme Performance tier will be of a single disk type, composed of eight Flash disks configured in a RAID 1/0 storage pool as shown in Figure 31.

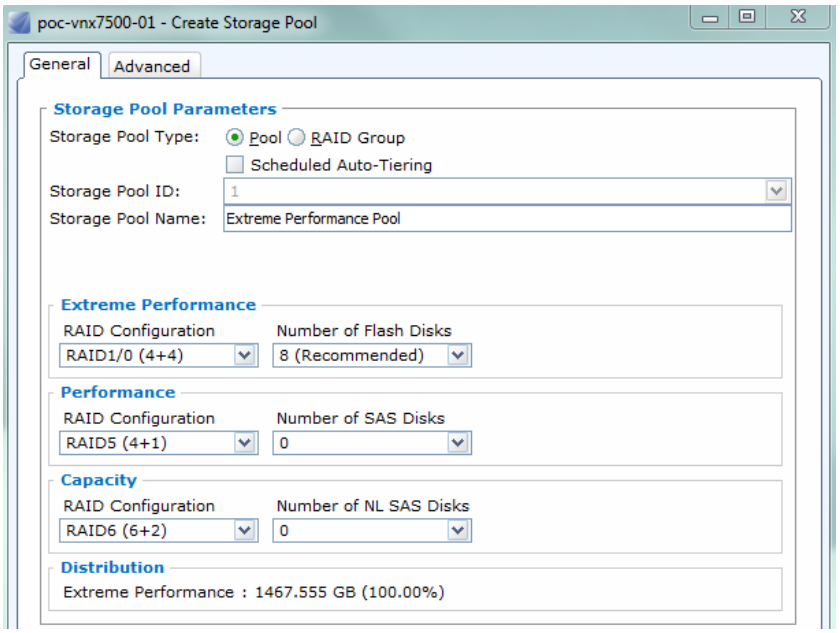

Figure 31. Extreme Performance storage pool creation

Two further storage pools are created (Performance and Capacity) using the same process within EMC Unisphere. The Performance tier consists of SAS disks only, is configured with nine disks, and is RAID-5 protected, while the Capacity tier consists of NL-SAS disks only, is configured with 16 disks, and is RAID-6 protected.

For LUN creation, the storage administrator specifies the desired LUN size and whether the LUN is to be thin or thick. After the LUNs have been configured in each of the storage pools, they are then masked to the ESXi server(s) and formatted as VMFS datastores.

Before importing the new storage devices into the Provider vDC in vCloud Director, storage profiles must be set at the vSphere layer by configuring the storage capabilities of the datastores as well as the virtual machine storage profiles.

The storage profiles can automatically be determined by the VASA client on the VNX, which provides an extensive list of storage as shown in Figure 32. Administrators can also add new storage capabilities if a particular combination of data services are not represented by a storage capability.

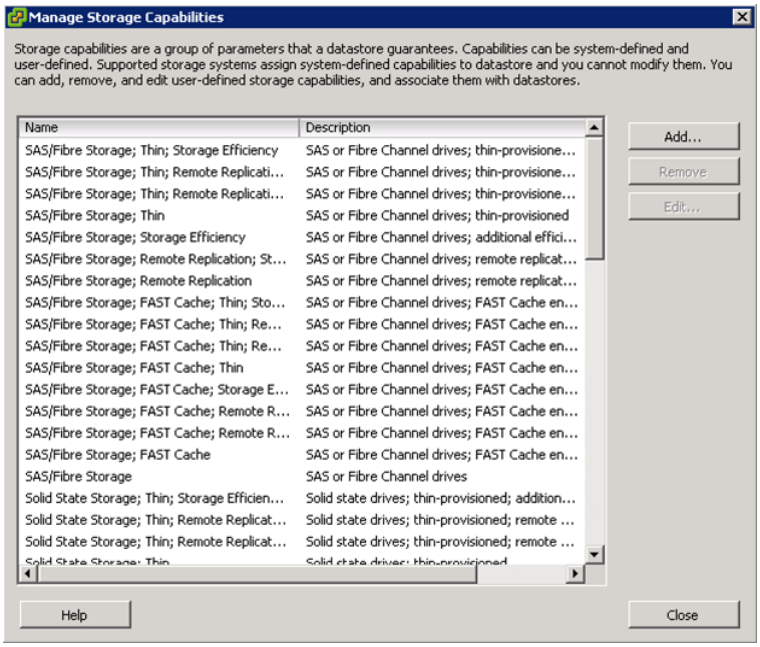

Figure 32. Storage Capability list provided by VNX storage

In order for the VNX to automatically set the storage capability of the datastores, the storage provider for the array must first be set up in vCenter, as displayed in Figure 33. EMC VNX platforms running Operating Environment v5.32 and later, run the required VASA client natively on the array in order to communicate with vCenter.

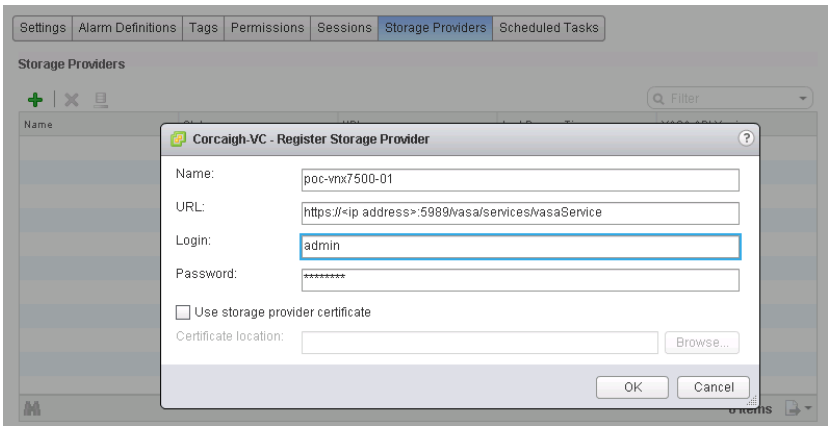

Figure 33. Register VNX storage provider via vSphere Web client

Alternatively, vSphere administrators can manually configure the storage capabilities of the datastores with their own customized storage capabilities as shown in Figure 34.

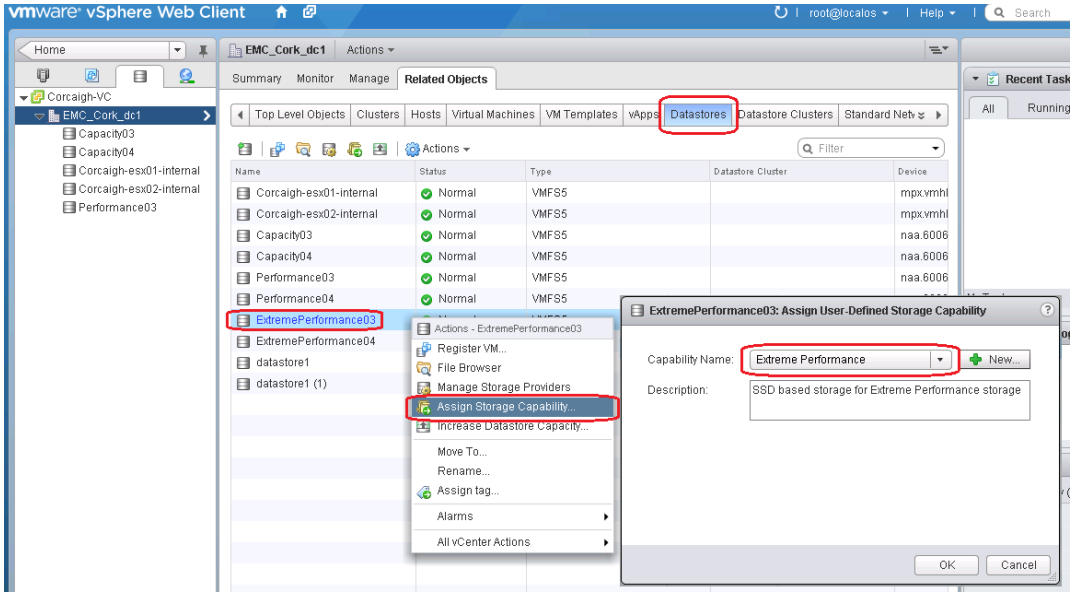

Figure 34. Assigning storage capability to datastore via vSphere Web client

After the datastore storage capabilities are configured, virtual machine storage profiles must then be created in vSphere (shown in Figure 35). These storage profiles dictate the quality of storage that the individual virtual machines are to reside on and must be mapped to the datastores that have previously been classified according to their capabilities.

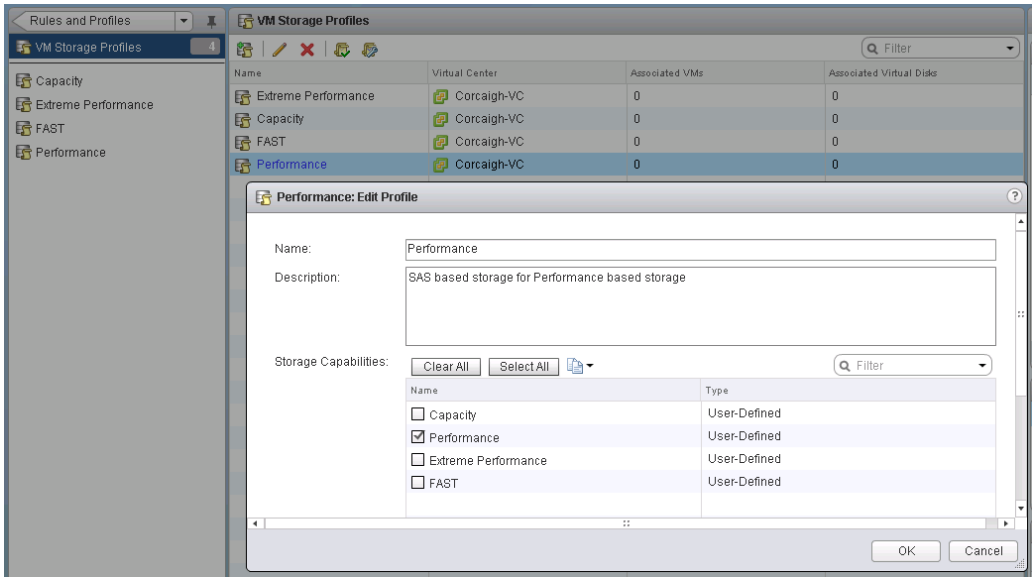

Figure 35. Example: Assigning 'Performance' level storage to virtual machine storage profile

As shown in Figure 36, the virtual machine storage profiles are then automatically exported to vCloud Director where they can be viewed within the Provider vDC.

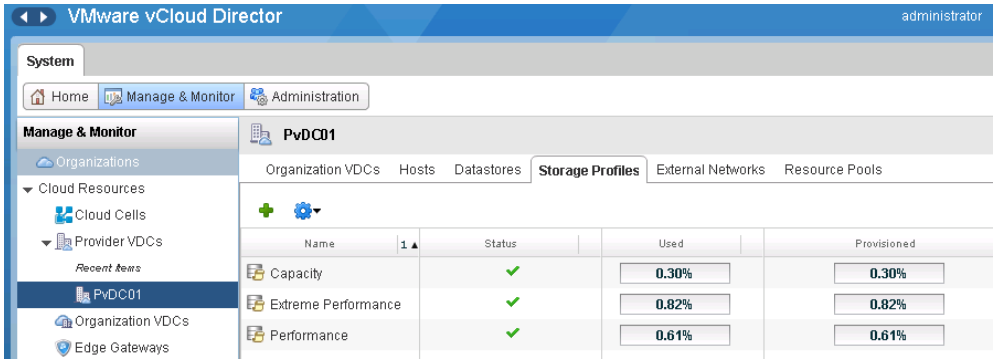

Figure 36. Storage profiles available in Provider vDC in vCloud Director

Using this example in Figure 37 where a three-tier vApp is required, each virtual machine within the vApp can have its own storage profile. The storage profiles are specified individually when the vApp is being created.

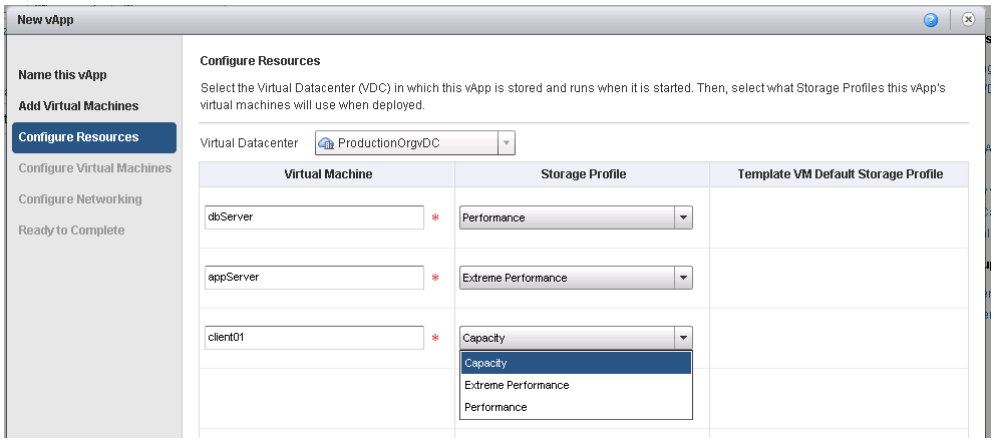

Figure 37. Configuring three-tier vApp across multiple tiers of storage

As shown in Figure 38, a default storage profile is set when the Organization vDC is being created, which means that when deployed by a vApp author, all virtual machines, unless otherwise specified, will use that storage profile and be located on that tier of storage.

Storage profiles apply to virtual machines, vApp templates, and media.

This default storage profile can be changed at a later stage in the Organization vDC Storage Profile tab.

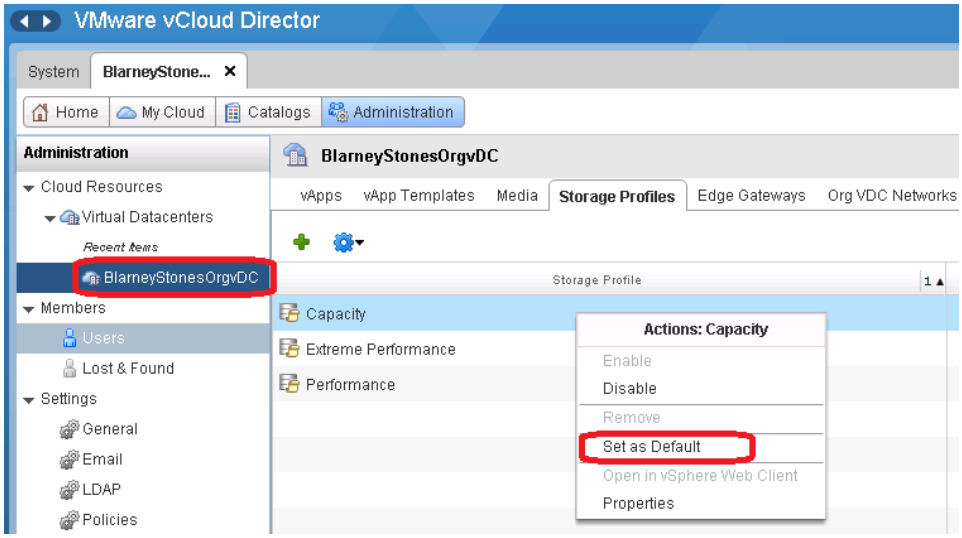

Figure 38. Capacity storage profile is set as default for BlarneyStonesOrgvDC

The example in Figure 39 displays the different tiers of storage available to the Organization vDC supporting the BlarneyStonesInc Organization. Flash-based storage is available in the Extreme Performance tier, SAS storage for the Performance tier, and NL-SAS for the Capacity tier.

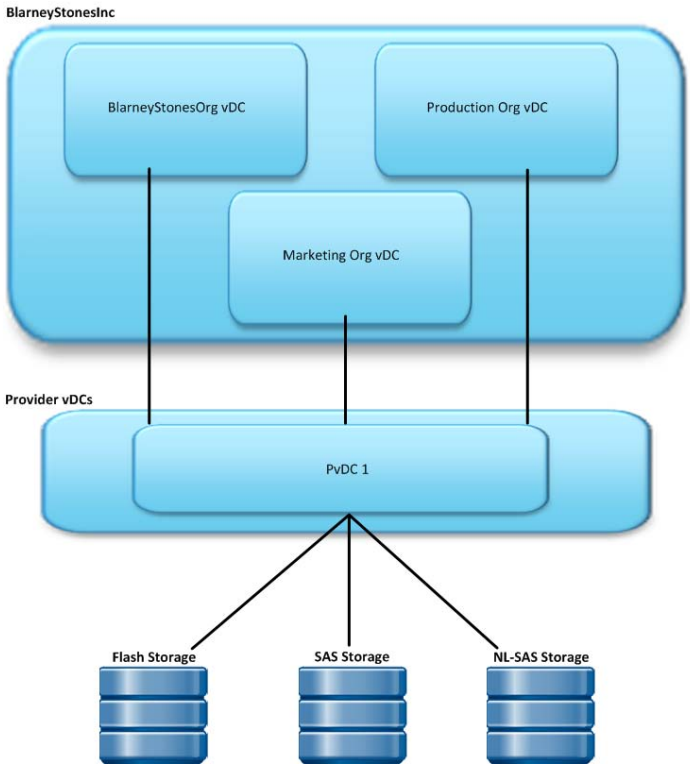

Figure 39. Single Provider vDC offering tiered storage to Org vDCs

This functionality, which enables the vApp authors to tier the virtual machines in their vApps as appropriate in each of the Org vDCs, is made possible by the tiered storage resources now available in a single Provider vDC.

As shown in Figure 40, the storage profile of a virtual machine can be changed at any time. By changing the storage profile of the virtual machine, the virtual machine and each of its VMDK files will be migrated to a datastore that is compliant with the selected storage profile.

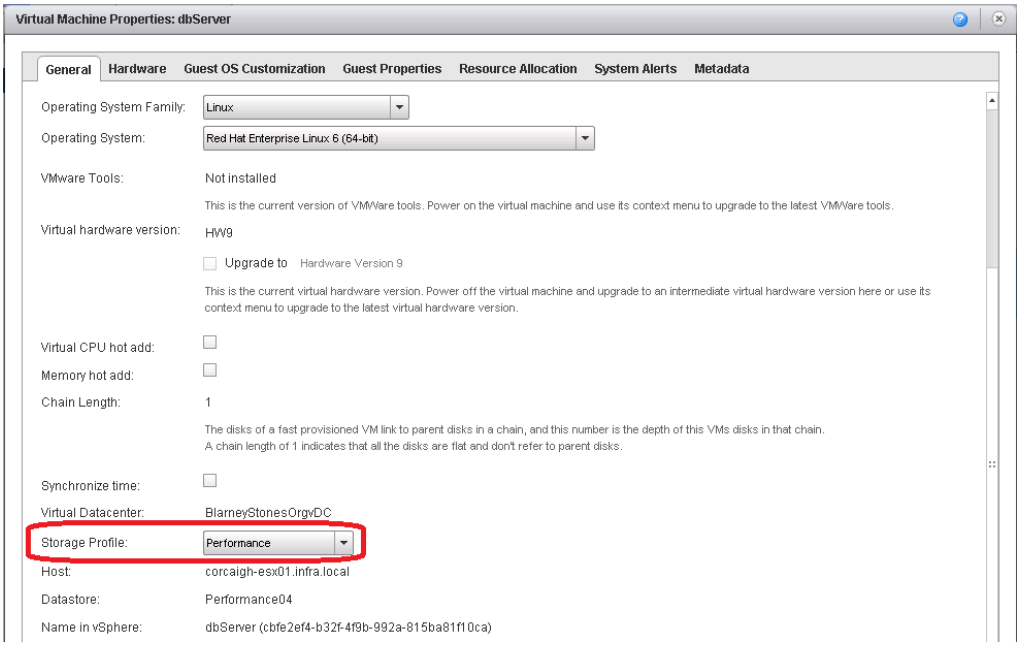

Figure 40. Selecting new storage profile to change storage profile of a virtual machine

It is possible to migrate the virtual machine to a compliant datastore is made possible by VMware Storage DRS interoperability being available as of vCD v5.1. Similar to storage profiles, the configuration of Storage DRS is done at the vSphere layer.

vCenter Chargeback Manager is fully integrated with the storage profile functionality in vCloud Director, and can be leveraged to accurately identify and track the storage profiles used by virtual machines in vCloud. Chargeback is possible based on the virtual machine storage profile or by the classification of the storage on which the virtual machine resides.

Changing service level of Provider vDC storage

When a service provider requires a change to the service level of the storage infrastructure that supports a Provider vDC in vCloud Director, the VNX Virtual LUN Migration feature enables a seamless and nondisruptive migration of the underlying resources, as illustrated at a high level in Figure 41.

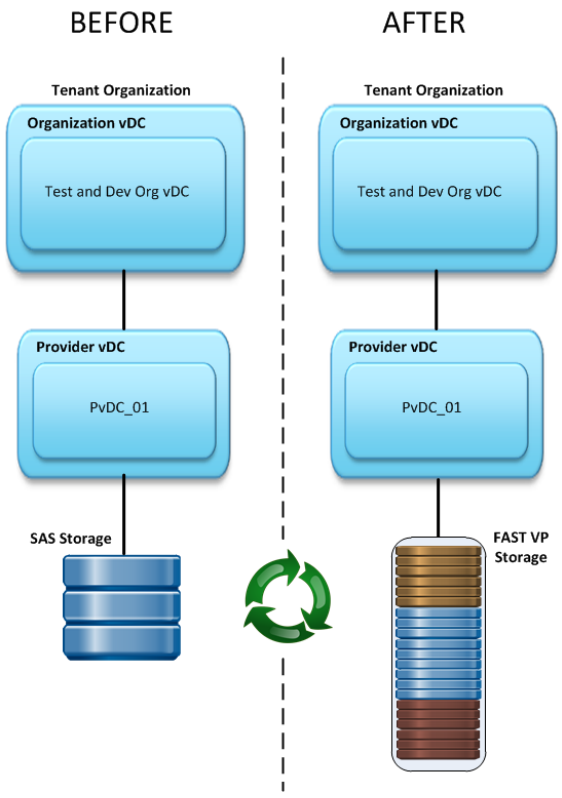

Figure 41. Migrating Provider vDC storage from SAS-only to FAST VP-enabled

The Virtual LUN Migration feature on VNX arrays provides a simple way of migrating data at the LUN level. VNX Virtual LUN Migration transparently moves data from a source LUN to the destination LUN of the same or larger size within a single storage system. This LUN migration can enhance the service level of the storage by migrating the LUN to a pool with different characteristics—such as disk type, RAID type, size, or FAST capabilities—while their production volume and applications remain online.

Beneath vCD, at the vSphere level, the ESX/ESXi server always sees the same device because the migration is masked at the backend. On completion of the migration operation, the original source LUN is destroyed and the new destination LUN assumes the **Nice Name**, **WWN**, and **LUN ID** of the source LUN. Therefore, no configuration changes are required anywhere in the vCloud environment.

Migrations are possible between all pool types, heterogeneous to homogenous, and vice versa.

The migration operation can be executed either through CLI or EMC Unisphere (shown in Figure 42). The user is required to identify the source LUN that is to be migrated and then identify the target LUN to which they intend to migrate to.

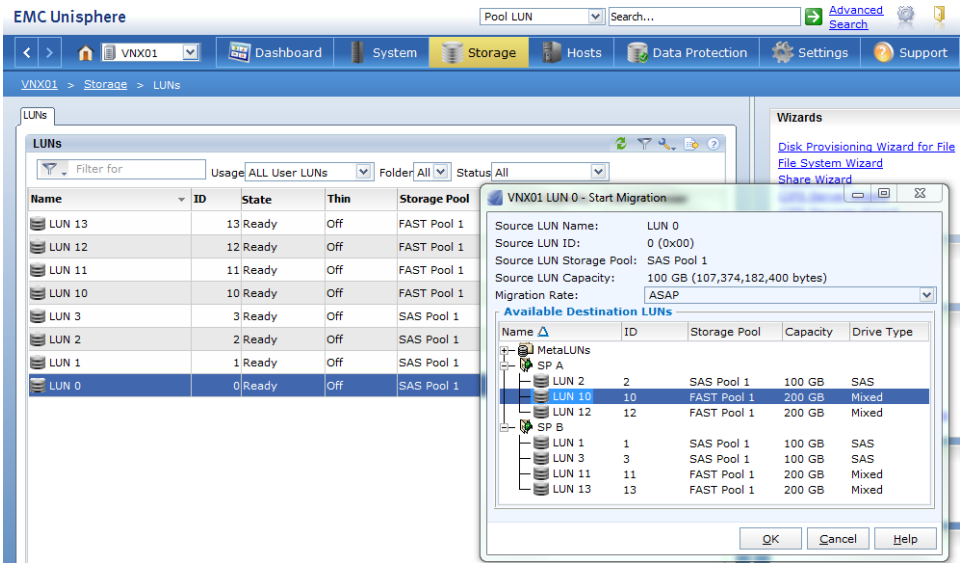

Figure 42. Creating and initiating migration operation of source LUN to target LUN

As the migration process is running, the system proceeds to copy the contents and blocks of the original LUN to the destination LUN. The migration driver handles the synchronization of both LUNs, the switchover of host operations from the old LUN to the new LUN, and the subsequent removal and unbinding of the original LUN. The migration process is an online operation during which the host has uninterrupted access to LUN.

Figure 43 shows the VNX LUN migration summary of all datastores in Provider vDC.

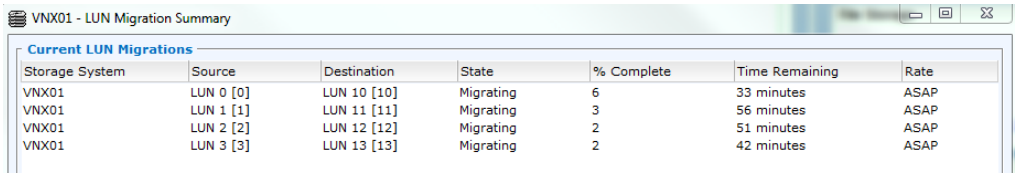

Figure 43. VNX LUN migration summary of all datastores in Provider vDC

The progress of the migration operation can be viewed via the LUN Migration Summary window in EMC Unisphere.

No other infrastructural configuration changes are required, either before or after the migration completes, as the new LUN assumes all of the properties of the original LUN.

A vCloud v5.1 environment using storage profiles requires the reclassification of the storage capabilities of the datastore in vSphere. A pre-5.1 vCloud environment would require all datastores or LUNs within a Provider vDC to be migrated to the new storage type so that all of the managed storage resources have consistent performance profiles.

vCenter Chargeback Manager can be updated with the relevant cost models and rate factors to accurately reflect and bill for the new storage service level being provided.

Configuring Provider vDC on NFS storage for vCloud catalog

You need to consider the location of catalogs for an organization and the type or tier of storage on which it is hosted. A catalog provides organization users with a library of content such as media, ISO files, and virtual machine templates. Public catalogs enable collaboration across multiple organizations where specific applications and utilities can be developed and shared between the various groups or departments in an organization. Authorized users and developers have the ability to upload and publish their systems via these public catalogs.

These files are static, do not require the read write performance requirements of production or 'active' systems, and can be located on a much lower tier of storage. vApps are available to deploy directly to any Org vDC from any shared catalog. The primary storage consideration for this type of content is capacity and may also be an ideal candidate for thin provisioned storage.

A specific Provider vDC and Organization vDC could be created to host this library of content that can then be accessed by all other Org vDCs. This enables a separate cost model to be applied to this storage through vChargeback.

Figure 44 displays some vApp templates available within a catalog. This catalog has been placed in a catalog vDC rather than the production or research and development Org vDC that leverages higher performing, more expensive storage.

Figure 44. Catalog placement in specific Org vDC

Media is available to mount to virtual machines from local catalogs only, which means that the media must first be copied locally to the Org vDC in which the virtual machine resides.

In Figure 45, the tenant has three Org vDCs, each being provided with storage from three separate Provider vDCs. The production and research and development departments have their own tiers of block storage, while the catalog media, available from the catalog Org vDC, is configured over Network File System (NFS) and shared to all other organizations.

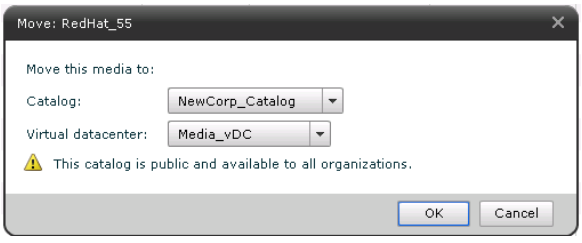

Figure 45. Moving or copying media to a specific vDC

Using EMC VSI for VMware vSphere

Storage resources can also be configured at the vSphere level by the EMC Virtual Storage Integrator (VSI) for VMware vSphere. The EMC VSI for VMware vSphere: Unified Storage Management feature can provision NFS datastores on Network-Attached Storage (NAS) and VMFS datastores on block storage that can then be imported as managed resources into vCD, as shown in Figure 46.

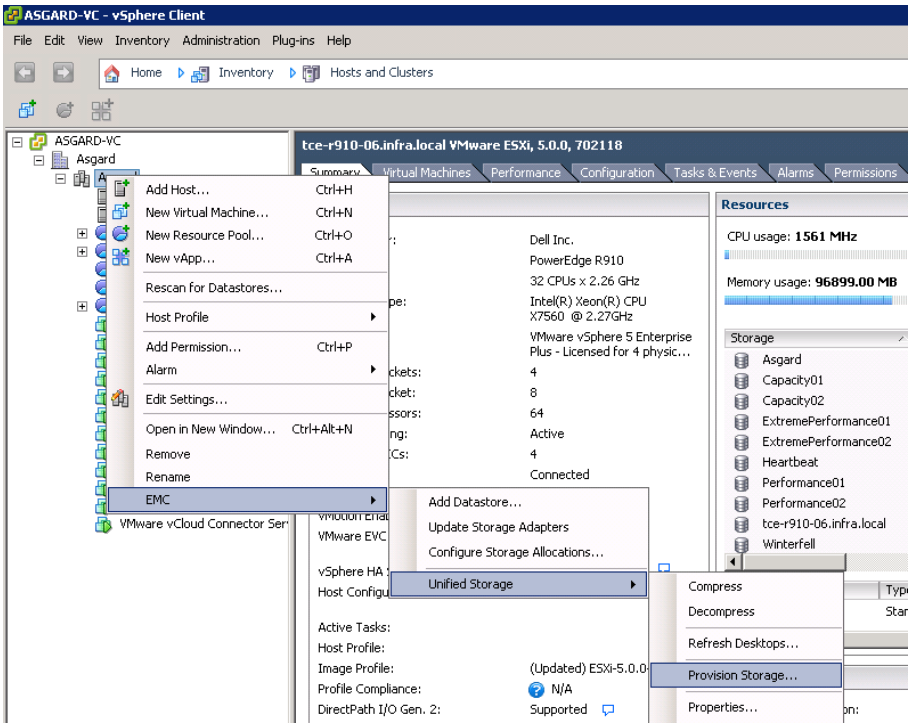

Figure 46. EMC VSI for VMware vSphere: Provisioning storage directly from vSphere

VMware administrators can use this feature to manage unified (block and file) storage in VMware environments via the existing vSphere client user interface.

The tiered storage resources are configured at the vSphere layer via the EMC VSI tool before being assigned to a vCloud Director Provider vDC, as detailed in Figure 47.

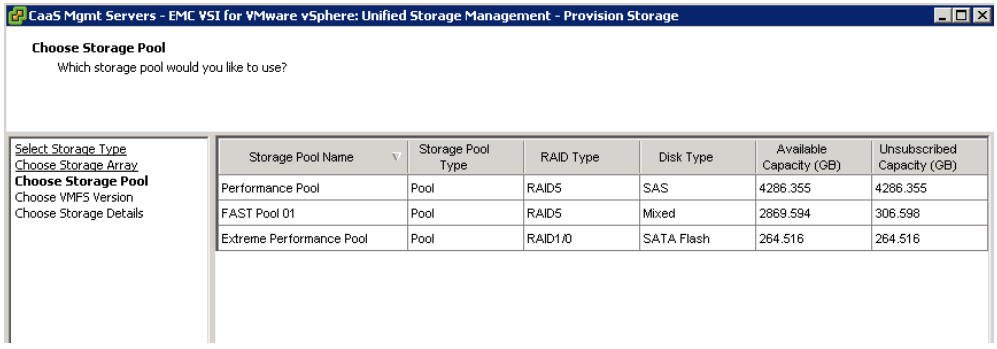

Figure 47. EMC VSI for VMware vSphere: Selecting storage tier from which to deploy

Conclusion

Summary

Service providers can increase storage efficiencies in their vCloud environments by leveraging FAST on EMC VNX.

The latest features of EMC and VMware integration can be leveraged to provide Flash-enabled tiered storage solutions that can integrate with and enhance the latest VMware vCloud functionality for profile driven storage.

A greater number of service offerings can be generated by service providers through a combination of EMC VNX storage and VMware vChargeback Manager.

Service providers can accurately meet service-level agreements for a wide variety of tenant organizations and end-users, while also making the most efficient use of the resources available.

When deployed with VMware vCloud Director and vCenter Chargeback Manager, the EMC VNX unified storage family provides the foundation for increased agility, services, and efficiency in cloud deployments for service providers.

Findings

The key findings of the solution are as follows:

- EMC VNX provided homogeneous and heterogeneous storage pools can be leveraged to provide storage tiering in VMware vCloud Director.
- Hybrid storage tiering, using different weighted FAST VP storage pools, backed by EMC Flash technology, enables service providers to offer a greater range of service levels.
- Service providers can optimize and protect their vCloud Director environments on Flash, SAS, and near-line SAS drives.
- EMC VNX FAST VP enhances the granularity of storage tiering in vCloud Director environments.
- Multiple tiers of EMC VNX storage can be aligned and integrated with profile-driven storage in vCloud Director.
- VMware vCenter Chargeback Manager can report on and bill for FAST VP enabled storage in vCloud Director.
- Service providers can meet a greater number of SLAs by taking advantage of tight integration between EMC and VMware products.

References

White papers

For additional information about EMC products, see the white papers on the EMC website or PowerLink listed below:

- *Using EMC VNX Storage with VMware vSphere*
- *EMC VNX FAST VP – A Detailed Review*
- *EMC FAST Cache – A Detailed Review*
- *Applied Best Practices Guide: EMC VNX Unified Best Practices for Performance*

Other documentation

For additional information, refer to the following documentations:

- *VMware vCloud Director Resource Allocation Models*

  http://www.vmware.com/files/pdf/techpaper/vCloud_Director_Resource_Allocation-USLET.pdf
- *VMware vCloud vCAT*

  http://www.vmware.com/cloud-computing/cloud-architecture/vcat-toolkit.html
- *vCD on Vblock*

  http://www.vce.com/pdf/solutions/vce-deploying-vcd-on-vblock.pdf