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Storage Virtualization Promises Agility in the Data Center

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STORAGE VIRTUALIZATION PROMISES AGILITY IN THE DATA CENTER

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Abstract

Data storage and protection has moved to the forefront of Information Technology solutions because the business value of data has gained in rank and importance in the world of internet commerce. Modern business models are built around instant and continuous data availability and they would not be able to function without this quality. This level of data availability requires data storage technologies to be of increased flexibility and higher performance. However the more sophisticated technologies pose a greater challenge to the architects of data storage solutions who are required to evaluate products of much higher complexity and administrators who need to manage and monitor these installations. New tool sets are required to leverage the promise of the storage virtualization technologies and extract their full potential for an agile data center. New tool sets for storage virtualization will bring the IT organizations into the position of data service provider for the business groups.

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Chapter 1 – Introduction

Importance of Managing Data Storage

Data storage is a place to put the information generated by applications and users during a business process. This information is vital to conduct business and its availability affects the productivity of teams across the organization. Managing the data and the storage for availability, accessibility, and reliability is imperative for the IT department. The IT department assigns highest priority to data storage access for computers and uses sophisticated tools to accomplish the task in a consistent and predictable manner. The agile business process, combined with stringent requirements to handle all data within the definitions of the business policy, elevates data management and, by extension, storage management, to two of the most important disciplines in the IT department. Data management must be anchored in business policies and procedures that address the strategic goals of the company, while storage management is anchored in the operational objectives of the IT department (Filks, 2010).

At the same time business data volumes in all industries and service sectors are growing anywhere from 40% to 60% annually (Villars and Perry, 2009). This growth is fueled by business processes that extract increasing details from existing data such as is the case in data warehousing applications or by the always-on business operation which generate more backups and snap-shots more frequently to protect against the eventuality of data loss. In addition government-mandated reports, audit rules and data-retention laws drive the number of datasets ever higher. While the CIO has to accept the dynamics in this environment she or he must also deal with generally flat or declining IT budgets and the resulting likelihood of staff reductions.

From the perspective of available technologies, IT departments have many product choices from multiple vendors to help them with these tasks. The challenge is the integration of the storage infrastructure management tools both with existing tools for the rest of the IT systems and with existing business processes and requirements. Just like the application solutions that do not share data seamlessly with other applications, the management tools neither integrate nor share data with others in the data center are islands of information and make the management of data storage more complex and time consuming, rendering the tasks of monitoring and troubleshooting impossible. Additionally, tools must keep up with the new features of rapidly evolving storage solutions from select vendors.

Recent Developments in the Data Center

Business units are developing more dynamic business models and demanding the IT departments to keep pace with the changing requirements. However, the traditional information systems and data center architectures are ill suited for this flexible business world. The trend has been to convert to a service-oriented architecture (Oracle, 2009). However, IT departments do not yet have the storage-management tools required for such agile computing environments.

Virtualization promises the agility in the data center required for today's dynamic business world. Virtualization refers to the abstraction of logical resources away from their underlying physical resources in order to improve agility and flexibility, provide opportunities for cost reduction, and enhance business value. In a virtualized environment, computing environments can be dynamically created, expanded, shrunk, or moved as demand varies (IBM, 2009).

With the advent of virtualization technologies, the modern data center operation has become more flexible (Goldworm and Shamarock, 2007). They are making the data center nimble and responsive to the ever changing needs of business customers. In particular, storage virtualization offers operational benefits such as availability, reliability and recoverability for managing business information. This technology has become an integral part of many IT operations and all major storage vendors offer some form of storage virtualization. This is not a coincidence of like product developments by the suppliers. Rather it is a tangible need to address the demands of business operations in what has become a very dynamic business world and with it, its IT operations. For IT organizations to stay ahead of these business requirements, technologies have to become available to address the exponential growth of data volumes and greater data Input/Output bandwidth demands from web-based solutions. In addition, IT had to respond to the more rigorous demands on business continuity and disaster recovery, performance, and more granular scale to store data at the right cost and performance level.

Statement of the Problem

Storage virtualization technologies look promising in theory, but they require far-reaching changes in the data center. This fact is not only a deployment of new hardware to replace the old as has been done many times over the years, but additionally a replacement of established and well-understood computing practices and procedures. The success of virtualization requires the combination of people, process, and tools (Barlow, 2010). For storage virtualization to bring measurable benefits, the IT staff must learn the use of new tool sets, develop new procedures to leverage the promise of the flexible computing environment, and absorb and manage the risk of changing over to the adaptable computing environment. With fundamental and widespread changes in an organization come risks, unanticipated problems, and a lack of historical evidence that such technologies will work or that when problems arise, they can be solved in a reasonable amount of time. The technology itself might therefore not deliver the desirable flexible computing environment, but replace one set of known problems and challenges with a new, and more importantly, unknown one. This paper will address what changes in process and procedures are necessary to leverage the benefits of storage virtualization while minimizing the risk of negative impact.

Specifically, the virtualization of storage arrays changes the handling and management of data. With virtualization, managing the environment becomes a great deal more complex (Bloor, 2008). These new requirements involve many aspects of the data center operation and staffing. Storage virtualization imposes a new set of procedures in managing storage area networks and storage arrays, because they invoke these resources in ways that are very different from the traditional approach. Existing tool sets, like those purchased from vendors or homegrown scripts developed over the years by the administrators, are not adequate in virtual architectures. They cannot report on dynamic relationships between a virtual server's data storage and physical data location, nor can they create alerts on over-provisioned storage resources. What is required is a clear understanding of how these new technologies work and a projection of the fundamental changes needed to adopt virtualization technologies in the data center. The use of storage virtualization technologies in the data center enables an agile computing environment, but requires new tools that will open and expose the additional layers of virtualization to integrate them into the administrator's tasks.

Project Scope

This paper will address the requirements for storage resource management (SRM) software in the modern data center. It begins with a review of storage technology developments over the last two decades and then discusses the introduction of new features that gradually increased the level of complexity in the management of storage equipment. It continues with examples of storage virtualization products available today from key vendors in the market, and how these products function and impact the work of administrators. The paper presents a list of management objects, the things the administrators must configure, monitor, and manage, in order to illustrate the many touch points in modern storage equipment. This list will then lead into the presentation of feature requirements for effective storage virtualization management.

Chapter 2 – Review of Literature and Research

History of Storage Architectures

Storage administration has been the job of the system administrators in the data center since the first computing environments were established. However, only with the advent of storage area networks and, more recently, storage virtualization technologies have administrators been challenged in keeping up with the pace of new product releases. Gradually, the complexities increased with the introduction of new technology. From product generation to the next, the number of management points increased as well. There are so many elements to manage, and the tasks have become so specific, a new job descriptor has emerged. There are now storage administrators who manage the data storage infrastructure of an enterprise. Just like server or network administrators, these specialized administrators are focusing on only one part of the IT solution. This specialization was necessary because the tasks have become too complex for the same group of individuals to be proficient in the administration of servers, networks, and storage arrays. In smaller companies this separation of administration might not be feasible and the same administrators must be able to maintain servers and storage solutions. In such cases, they do it most often with the periodic assistance of an outside storage consultant. In both situations, it is vitally important to have good tools available to manage the systems.

The beginning of externally attached disk drives.

The first external storage products were hard disks mounted in an enclosure, with a common power supply, SCSI bus and cooling fans. They were commonly referred to as Just-a-Bunch-of-Disks, or JBOD. When the servers had direct attached storage in a JBOD, the management was much simpler because there were fewer elements to take care of. There was the SCSI ID between 0-7, later expanded to 15, with one ID taken up by the SCSI initiator. As Figure 1 illustrates this configuration left 7 or 15 disk devices per initiator. These setups required very few parameters to configure and thus were easy to manage and tune. In addition the setups were static; once installed there were few changes to the system.

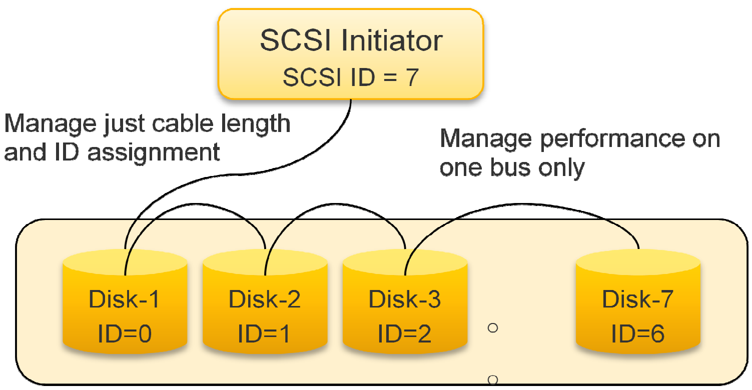

Figure 1 JBOD

This storage product worked quite well and the administration was simple because there was generally no stacking of applications on the same server, and therefore, no sharing of capacity, bandwidth, or any other resource. Rarely were there performance issues in such setups and, when there were, the concerns were limited to one application, and a resolution was relatively easy to find.

RAID controllers, the first step in virtualization.

JBOD products had one major problem: a hard drive failure meant certain data loss. Hard drives have a much lower mean-time-between-failures (MTBF) rate than servers do, so it was not uncommon for an application to stop working until the failed drive was replaced and data restored from the backup media. This practice was a time-consuming process and data loss was unavoidable because all data between last backup and time of drive failure was generally lost. The storage solution providers developed products that would protect against a single hard-drive failure with the concept of redundant disks. This solution was implemented in Redundant Array of Independent Disks, or RAID, which writes the data to physical disks in a calculated pattern for fault tolerance. Striping of data distributes the load over multiple hard-drives, resulting in higher performance. A number of different RAID levels have been developed but only three are in practical use (Troppens, 2004). These are RAID-1 which writes data to one disk and mirrors it to a second, and RAID-10, which mirrors and then stripes data across four disks. RAID-5 calculates parity and writes the striped data plus the parity across three or more disks in a group. If one of the disks fails, the RAID controller can reconstruct the data of the defective disk using the other disks. The parity in these stripes is interleaved, or rotated among all disks in the group to avoid performance problems with a single disk holding all the parity data. Typical RAID-5 configurations consist of five (4+1) or eight (7+1) disks, as illustrated in Figure 2.

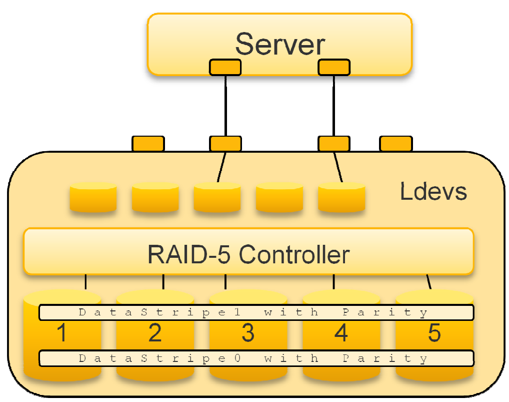

Figure 2 RAID-5 Controller

In modern RAID controllers, the capacity of a group of disks is divided into smaller logical devices (ldevs), which are then presented to the server. The controller composes a number of data stripes into a logical disk. This abstraction of a logical disk from a number of physical drives is one of the early elements of storage virtualization (Massiglia, 2003). A logical disk can be of any size up to the total capacity of the disk group. This fact allows the creation of logical disk sizes to match the exact requirements of the application rather than being dictated by the physical size of the disk.

The storage area network (SAN) is introduced.

During the late 1990's SAN technology entered the stage and was adopted very quickly. It grew out of the need to have access to data by multiple servers running the newer business application. The vertical organization of IT systems, sometimes referred to as silos of decentralized servers and storage systems, was not well suited for the new, integrated business software developed by Oracle, SAP, and other software powerhouses (Frost & Sullivan, 2009). A storage device attached to servers on a fibre channel network separate from the local area network could be accessed from many servers concurrently and would centralize the business data again as illustrated in Figure 3. However, while the fibre channel network components seemed simple enough, after all, by this time we had witnessed the deployments of IP networks in every solution, the management of the data residing on SAN attached storage arrays was much more complex. While a local area IP network would remain relatively stable after the initial configuration, a SAN had to be modified frequently as a result of being in the data paths between the servers and the storage arrays, and the dynamic requirements of storage configurations. As a result, administrators spent more time taking care of storage solutions and becoming more sophisticated and educated about the administration of storage arrays. This is one of the reasons why the ratio of server-and-storage-administration cost to procurement-cost has changed, a fact the industry has not overlooked. The Operational Expense (OPEX) is growing faster than the

Capital Expense (CAPEX) and is becoming a major factor for decision makers to implement virtualization (Tanejo Group, 2009).

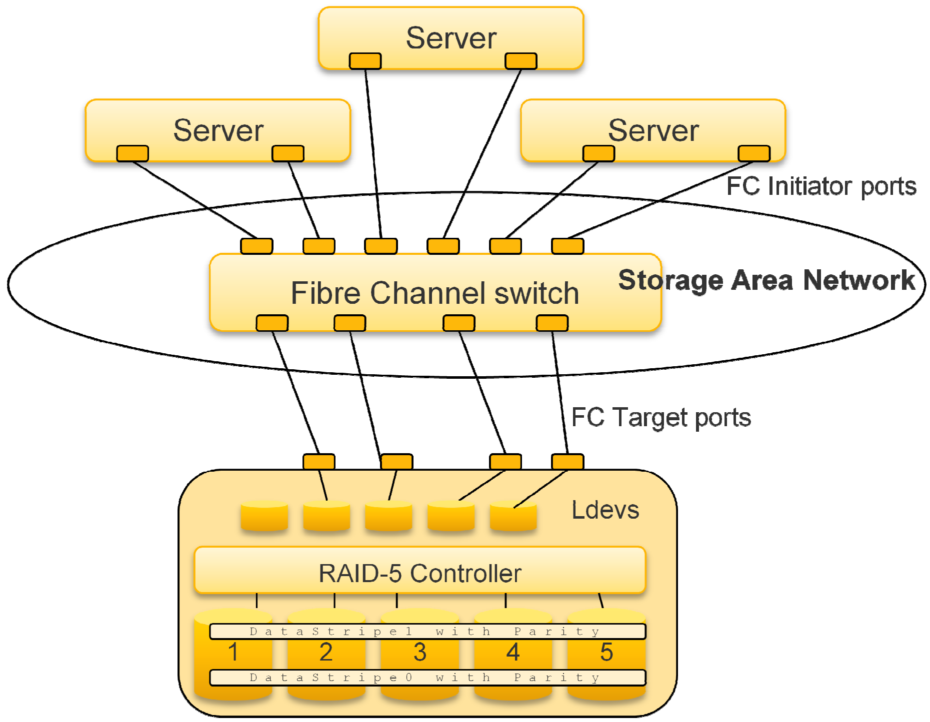

Figure 3 Storage in a SAN

The storage virtualization layer.

Even though the SAN allowed the interconnection of servers and storage arrays, there were still issues with the flexibility of data location, service requirements, and variations in functionality among vendor products. A server consuming space on one array could not obtain more space if needed from another array without more elaborate changes to the data path (SAN) configuration. When a server needed additional capacity, such capacity might not be available on the array to which the server was attached and space on another array might need to be accessed. This situation was especially true with data centers adopting server virtualization needing a more flexible storage infrastructure to leverage the features of server virtualization such as data movement, backups, and disaster recovery. In those situations, all of the servers in the cluster would be required to have access to the same data and storage locations to allow the unimpeded movement of virtual machines and their data.

Still other issues were born out of new business requirements. Until now, data was placed on a storage tier and left there for the duration of its life. This storage allocation method is a very inefficient use of storage space since the business value of data in the modern business process is initially very high but then decreases in a relatively short period of time. To address the issue, storage architects had to design a way to migrate data without disruption to servers and applications from a tier-1 storage array to a lower tier to match the data value to the cost of the infrastructure on which it resides. Likewise, there needed to be a way to promote data to a higher storage tier to address the need of a business cycle, such as the end-of year data-processing cycle. A storage administrator does not have the information to match the requirements for the data to the physical storage devices. In large environments it would be too much to deal with the needs of every single virtual disk assigned to a server. Therefore, corresponding data classifications needed to be created that would align the data value with the storage location on which it resides. An entity is required which creates such data profiles automatically based upon the data usage (Troppens, 2004).

Another challenge faced by IT departments was the renewal of storage equipment at the conclusion of its useful life or at the end of a lease period. It is a time-consuming and disruptive process to migrate data from old equipment to new equipment. The incompatible storage spaces had become a major problem for two reasons. First, data could not be migrated directly from one vendor’s storage to another’s without disruption to the service. Network appliances

(FalconStor, 2010) or host based solutions (Veritas, 2010) needed to be deployed to accommodate the relocation of data, but such deployment required an outage in most cases. Secondly, moving data in the primary data center from one storage array to another could cripple a disaster-recovery setup and procedure.

Solutions providers developed technologies to address the problem of integrating storage space into enterprise storage solution, making it possible, at least in theory, to have one unified storage space for the entire enterprise. The concept is straightforward as illustrated in Figure 4: Add an abstraction layer between servers and storage space in order to scale the storage solution horizontally and vertically, thereby expanding the capacity and performance of the storage infrastructure.

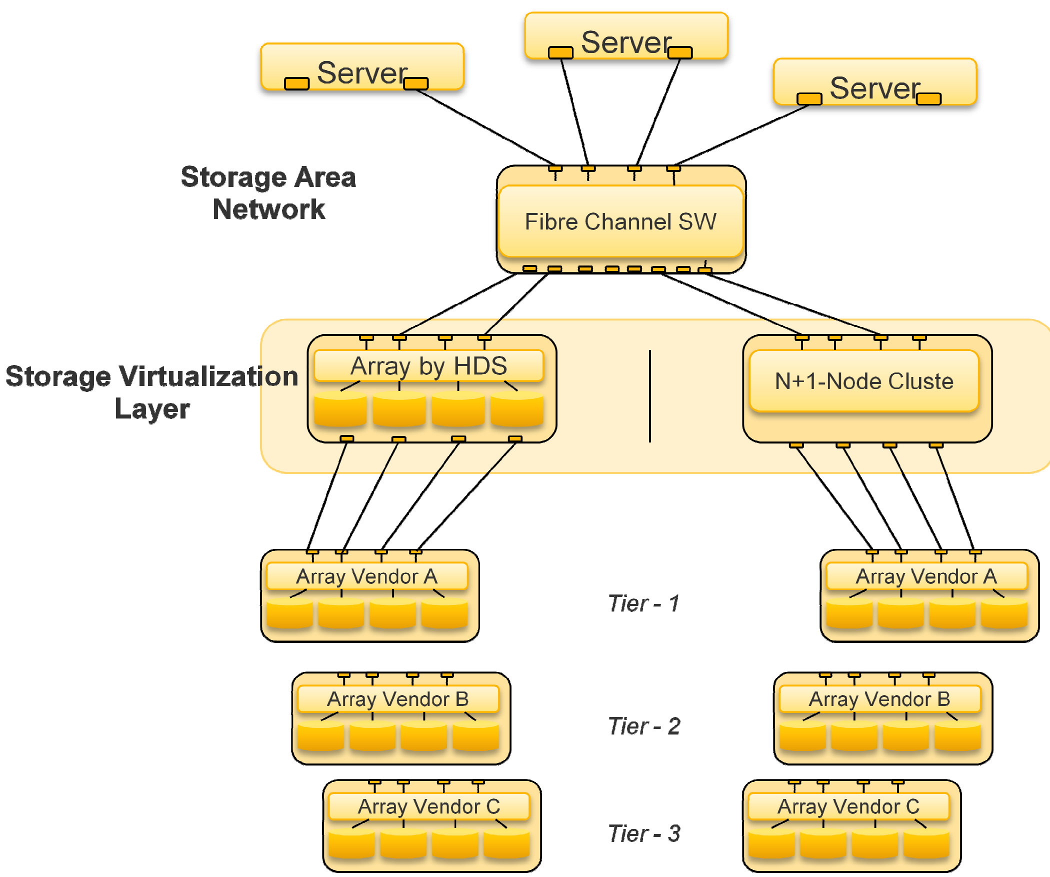

Figure 4 Storage Virtualization

Called virtualization, this method refers to the abstraction of logical resources away from their underlying physical resources in order to improve agility and flexibility, reduce costs, and thus enhance business value. In practical terms, this technology allows administrators to create, destroy, modify, and resize server and storage setups much faster compared to traditional computing environments.

There are many advantages to the virtualization approach, but main objectives are scalability to address data growth and higher bandwidth, flexibility to deal with dynamic business requirements, and containment of management costs by managing all storage space with one virtualization solution. In order of importance, these objectives are as follows:

- Scale-out computing:
    - Increase operational efficiency and flexibility
    - Add capacity in step with business requirements
    - Provide bandwidth where it is needed
    - Enhance overall business resilience
- Establish tiered storage:
    - Store data on appropriate tier based on bandwidth requirement
    - Promote and demote data based on business value
- Heterogeneous storage space under the umbrella of one management tool:
    - Simplify deployment and management of virtual disks
    - Allocate and de-allocate storage space
    - Ability to mask complexity of underlying storage arrays
    - Reuse and re-allocate equipment regardless of model and brand
    - Improve capacity and bandwidth utilization

    - Decrease IT costs and business risks

- Enabling new forms of innovation
    - Storage as a service is an enabler for (internal) cloud computing
    - Charge back at the correct rate based on capacity and I/O bandwidth
    - Spin-down disks based on access patterns to reduce energy costs
    - Deploy latest generation of storage arrays directly to existing storage virtualizer

Three designs have established themselves in the market as the technology leaders. Two are based on network appliances while the third is a storage-controller based design. All three work on the principle of abstracting the physical ports and blocks of data on specific sets of disks to the volumes or files that servers and applications need to access.

1. Storage Controller based, by HDS Universal Volume Manager®
2. Network based symmetrical, by IBM Storage Virtualization Controller®
3. Network based asymmetrical, by EMC Invista®

All three of these concepts are discussed in chapter 3. Controller-based and network-based designs offer advantages in certain functional areas, but none is the perfect answer in all situations of storage virtualization. The limitations are not in the product implementation, but in the limits of the architecture necessary to support business process functions such as data replication for disaster recovery or performance scalability.

The storage architect and administrator now have the flexibility to work with available storage space under one unified storage management program. With storage virtualization many elements are integrated and no longer need to be managed separately. This fact lowers the overall management cost. However, it cannot be dismissed that each layer must still be managed, even if it is a product from the same vendor. The storage array providing capacity to the virtualization layer must still be configured, managed, and monitored, if only during the initial setup. So the storage virtualization introduces another layer, but does so with the net benefit of lowering the overall management effort and cost.

Other storage technologies.

This chapter cannot be complete without mention of other important technologies available in storage solutions from all major vendors. They have been designed to address real problems in data management and to serve a tangible function in the IT solutions.

One such technology is the dynamic provisioning of volumes, a way to address the underutilization of assigned capacity. Because increasing the size of a logical disk is difficult to do but necessary during life of the application, an administrator's easy answer was to overprovision or allocate more capacity than initially required. This fact forced the procurement of larger capacities than necessary, usually at a higher price, then the allocation of capacity later, when the price of the same commodity has come down by some percentage. Dynamic provisioning allows the administrator to pre-allocate a large storage capacity but the array only uses actual capacities and allows the server to grow this capacity over time. By some estimates this method is able to improve storage capacity utilization by up to 50%. (Palmer, 2008)

Another technology is the virtualization of internal components such as cache memory and processors. Rather than assign these hardware resources to a specific purpose or function, they are shared within the system and can do work universally. This approach is a big step toward the balancing of performance and the elimination of hotspots within the storage array.

The technology has been in use on servers and operating systems for many years where memory and processors are shared routinely.

Included in these technologies is the path management, designed to offer path redundancy in the data I/O path. Not only does this type of management provide protection in case of a path failure anywhere along the IO path, but also allows for IO balancing over two or more paths for performance improvement. In addition, the path management allows for non-disruptive upgrades to hardware and software components within the data paths by allowing one path to go offline while maintaining data access over the remaining paths.

Chapter 3 – Available Storage Virtualization Products

Difference between Traditional and Virtual Storage Servers

The traditional storage array's major shortcoming is its fixed limit on capacity and performance. If either resource is exhausted, an additional array must be deployed. Furthermore, the capacity allocated is the capacity used, regardless of how much data the user is putting on the array. The challenge for the administrator is a constant battle to balance demand and available resources which results in increased operating costs.

The virtual storage arrays offer relief from these issues by allowing the administrator to allocate virtual capacities and add actual capacity to the pool as needed. Virtual storage arrays allow for much easier storage management thereby reducing operating costs.

Two concepts of storage virtualization architecture have prevailed and share the majority of the market. Both concepts create an abstraction between the storage arrays and the servers to utilize heterogeneous storage space. One concept is implemented in the storage area network, the fabric, as a cluster of server appliances, or with a so-called split path in intelligent fibre channel switches. The other is implemented in a storage controller with extensions of features to a regular storage array.

Virtualization in the Fabric

This design inserts servers or network appliances into the storage area network. The individual nodes provide the block data mapping between the virtualized disk and the storage capacity on the storage arrays. Because of this direct control, the virtualization engine can also be used for advanced functions like copy services, tiered storage space, and access control, even in heterogeneous environments. These functions are completely transparent since the individual storage arrays are essentially demoted to providing reliable storage space only. Because the nodes cache data, the latency in the data path is minimized.

To assure high availability, the nodes are deployed in pairs and configured as a cluster. This is an absolutely mandatory step as the storage virtualization layer is relied upon for all data access in the enterprise. The clustering of server nodes is a very mature technology which has been in use for many years. It is a low-risk architecture and relatively straightforward to implement and maintain. The storage administrator must pay close attention to storage provisioning from the arrays on the back end and be absolutely certain that all nodes can see all data storage. This requirement is not particularly difficult in smaller environments, but it can grow into a major challenge in setups with thousands of disks assigned to the storage virtualization solution. This challenge is especially likely when active–passive paths are in use and it is not obvious when a passive path is off-line for a disk. The virtualization software administrator must have a way to check for path redundancy and alert for any error condition.

A two-node cluster has a limited bandwidth and it can be exhausted after some level of I/O activity. There are ways to scale the cluster horizontally to increase the I/O bandwidth, to attach more storage capacity and to achive better performance. A two-node cluster can grow to a four, eight or even a sixteen-node cluster. However, as it scales horizontally, the complexities increase as well, some would argue more quickly than the enhanced performance. For example, each node must be assigned to an I/O group, which is another way of saying the nodes in the cluster must be subdivided, as well as the storage space they manage. This requirement makes the administrators task more complicated as the I/O group must be managed as part of the storage virtualization. I/O groups are a sub-element of storage virtualization and must be managed, configured, monitored, and measured.

There are limitations to this architecture, mainly in scalability. The aggregate bandwidth is limited by the internal bandwidth of the nodes since all data must pass through the nodes. Even with high bandwidth architectures of PCIx and PCIe buses inside the nodes, and low latencies in the nodes, the numbers might not scale to required levels of an enterprise-wide solutions. Where performance limits become a problem, some servers and their applications might need to be isolated from this architecture and attached in a closer link between server and storage. This approach would not be unusual as every design is a compromise of matching requirements to a solution. A corner case requirement has its own demands and might justify departing from the normal deployment strategies.

Virtualization in the Storage Array

This design leverages the capability of storage arrays such as high availability and advanced data management functions. The storage controller is the virtualization engine for attached storage arrays, but it can also provide internal, usually Tier-1, storage space. The external heterogeneous storage space can be tiered for most economical use and data can be moved non-disruptively between tiers. The same function can be used to evacuate data and transparently retire end-of-life equipment. This feature is extremely valuable because data migration is are a very time-consuming and high-risk process without a virtualization engine, and usually requires at least a short outage when data paths swing over to the new devices.

All functions of the array controller are available to manage data, even on externally attached heterogeneous disk space. This feature allows the setup of mirrors, both to local and to remote arrays and snapshots using the same engine. This flexibility is a desirable aspect of virtualization in the storage array not just from a cost perspective but also from a license management point of view. End-users must manage licenses not just for compliance, but to insure the correct license level is available for all functions and to insure against expiration of such licenses that impact the environment.

Storage virtualization on storage controllers is easier to expand since one system has much higher bandwidth than a network appliance that is built from generic server components. However, its bandwidths are not limitless and at some point one storage controller might not be enough to handle the entire work load. When the configuration deploys a second array, the management becomes twice as involved because every aspect point in the first array now must to be done in the second as well. This increased workload is an unavoidable consequence of any resource becoming exhausted at some level of activity. But the efforts to manage these environments grow more in step with the available bandwidth than the network node solutions do.

Summary of Virtualization Technologies

Storage vendors list many reasons why one technology is superior to another. Customers need to understand the advantages and disadvantages of each product and that no architecture provides the perfect storage virtualization solution. It is incumbent on the customer to prioritize each feature and decide which product is most suitable for the customer’s data center. The only way to do that is for the customer to become educated on how the products work and what changes they will impose on the operation of the customer’s data center.

Chapter 4 - Challenges of Managing Virtualized Storage Solutions

Need to Manage Has Grown Complex

The data path from the physical, and even more from the virtual, server to a physical disk traverses many layers, often from multiple vendors, and uses many shared resources. These resources must be configured, controlled, measured, and reported for the always-on environment to live up to its name. Administrators want better management tools for transparency and control over the virtual environments (Bigelow, 2010). The storage solutions available today have many touch points and require very complex tasks from the administrator. Ironically, some of these complexities at the equipment level are a result of the effort to create more flexible storage solutions at the data-center level.

Items of Configuration Management

Let us now look at the management items of a storage environment with virtualization technology. These items must be considered by the architect and the administrator alike. For each item the parameter values vary from a simple Boolean variable to elaborate numeric values interdependent with other variables. This range is because many of the parameters control a shared resource. How well it will perform depends on how the resource is used overall for one individual part or I/O path.

The extensive list (Table 1 Virtualized Storage Configuration Management) illustrates the many touch points the administrator must be aware of.

Table 1 Virtualized Storage Configuration Management

Feature / Component	***Purpose***
In the Virtualization Layer	
• Total bandwidth	Must address performance requirements of enterprise storage space
• Paths redundancies in cluster	Each node must have access to all data
• Node redundancy	One node failure does not impede access
• SAN configuration	Proper zoning of all FC ports
• HBA configuration	For target and initiator HBAs
• SAN security	Access control to logical disks
• Cache size	Set cache partition and stripe size
• External disk space	Add and configure virtualization layer
• Logical disk size	Select appropriate size for applications
• Pool type, size and thresholds	Select appropriate RAID level, size, and monitoring thresholds
• Advanced features like data replication	Local or remote copies must be configured, managed and recorded.
• Access control	Who can manage this equipment
On the External Resource/Disk Space	
• FC port speed	Set speed to match on initiator, FC switch and target ports
• FC port security, worldwide name (wwn)	Allow or block unwanted initiators
• FC port usage	Show how many initiators attached to ports
• FC port function	Target or replication to other arrays
• Paths redundancies	Each node must have redundant access
• RAID level	Select RAID level to match storage tier
• Logical disk size	Select appropriate size for applications
• Logical unit stripe size	Match it to I/O profile and file system
• Logical unit security (access control)	Allow or block access to logical disks
• LUN ID	Set ID number for host LUN
• Queue depth aggregation	Set QD per LUN, do not exceed max total allowed per port.
• Cache size	Set partition and size for best performance
• Cache configuration	Global, dedicated, partitioned, or reserved for critical applications

There is no one tool which unifies all of these features under one GUI with a relational data representation. Instead, individual element managers must be used to manage the related sections. For the data access path only, not including the application and server specific tools, five tools are required to manage it: 1) The host bus adaptors (HBA), 2) the multi-pathing software, 3) the storage area network (SAN), 4) the storage virtualization device, and 5) the storage array. There is no integration of all these element managers into one management tool. At best there is a link-n-launch from which to enter from one tool to another. For example, the HDS tools allow administrators to create links into the Cisco Fabric Manager or Brocade Data Center Fabric Manager.

Items of Performance Management

The configuration management is only part of the challenge. In any shared environment a balance must be struck between resource allocations to one entity without negatively impacting the rest of the environment. This balance is not always possible since resources are limited and resource demands by individual users vary based on business requirements, often times tied to a business cycle. The administrator is faced with the difficult challenge of balancing resources for all users while also prioritizing resources based on service level agreements. Unfortunately, the moving target of resource demands and the static configuration of the environment create opposing forces. Unlike server virtualization where dynamic resource allocation of processor and memory is well developed and mature, such is not the case with storage virtualization. It would benefit an application if I/O bandwidth and storage capacity could be allocated and de-allocated dynamically to address a temporary spike in demand. However, there are no storage products currently on the market that can do these functions. The likely reason is that the input parameters for a deterministic decision model are at the data center level and therefore much more complicated to gather and implement than dynamic re-allocation of local resources in a server.

Table 2 Virtualized Storage Performance Management

Feature / Component	***Purpose***
SAN Switch Side	
Port speeds	Verify speeds match on initiator and target
Port usage	Verify port utilization is below 50 % of capacity
Redundant paths	Verify balanced workloads on all paths
ISL link aggregation	Aggregate I/O workload must not exceed trunk capacity
Virtualization Equipment (array or servers)	
FC port processor	Verify shared resource is not overloaded
FC port speed	Match speed between initiator and target
Redundant paths	Balance workload equally among paths
RAID level	Match to requirements of I/O profile
Logical unit stripe size	Match to I/O profile and file system
Queue depth aggregation	Verify QD per LUN and aggregate per port
Cache size	Set partition and size for best performance
Back-end performance	Processors running at or below 50%
Back-end disk Configuration	Match to I/O profile
Back-end disk performance	Enough physical spindles for requirements
External Resource (virtualized resource)	
FC port processor	Verify shared resource is not overloaded
FC port speed	Verify speeds match on initiator and target
Redundant Paths	Balance workload equally between paths
FC port function	Target or Replication to other arrays
RAID level	Match to requirements of I/O profile
Logical unit stripe size	Match to I/O profile and file system
Queue depth aggregation	Verify QD per LUN and aggregate per port
Cache size	Set partition and size for best performance
Back-end performance	Processors running at or below 50%
Back-end disk configuration	Match to I/O profile
Back-end disk performance	Enough physical spindles for requirements

Just like the table for configuration management (Table 1 Virtualized Storage Configuration Management), virtualized storage performance measurement and management consists of a long list of items. The administrator must have insight into the parameters and knowledge about the baseline values in order to plan expansions, additions of servers, and investigation of a performance problems.

Managing the Storage Virtualization Layer

Storage management tools for storage virtualization solutions ideally address all of the following topics, as grouped by administrative procedures:

1. Configuration of resources from the storage array to the servers

- The storage administrator configures a disk and maps it to specific storage ports to which the server has access to. In its path and on the disk are many shared resources. At each juncture of the path, the administrator must have a way of verifying what resources are shared. This mapping of information is needed in configuration reports to verify proper connections of a server to the storage, and to confirm that redundant paths are present and have appropriate bandwidth for expected performance levels.
  - Disk access is secured by mapping the addresses of the host bus adapters to the target ports on the storage. The storage administrator must have a report of these maps to see the relationships among host bus adapters and target ports and to be certain that disk access is secured.
- The architect must know the bandwidth of each component in the data path and plan deployments and expansions accordingly. This information will determine how many servers can be connected to a port and how many disks can be shared over the same port.

- The information must be available for all equipment in the data paths regardless of the vendor source.

2. Management of storage virtualization components

- In the case of network appliances, these components are essentially servers running a highly specialized operating system and application. The SRM tool must poll these resources and provide configuration and management data of sub components such as CPU, memory, PCI buses and host bus adapters.
- The administrator must be able to manage the cluster of nodes to balance the workloads and to have resilience in the data paths. The SRM tool must also allow for non-disruptive software updates to components within the nodes by taking one node and the paths it supports offline, while other nodes continue to operate at appropriate service levels.
- In the case of storage controllers the storage virtualization components include everything found in a storage array such as front-end ports, cache memory, and back-end controllers with attached physical disks. The SRM tool must be able to report on the configuration of this array and its role as a storage virtualizer.
- Access to the functions must be managed and controlled. This management and control should be part of the company's security policies and integrated with existing access control procedures. Ideally, user identification and authentication is done on existing systems like Active Directory or LDAP. Where it is not, access control must be managed on the equipment itself which disassociates security control from the enterprise security system thereby increases risks as well as the workload of the administrators.

3. Management of the performance and operation of I/O paths

   - The servers and storage arrays described above have limited bandwidth to process I/O requests related to the hardware resources used.
   - The architect will need the performance metrics data of all the components within the data path to assess the overall health of the system. The same data is used for capacity planning where decisions need to be made about capacity expansions or the system bandwidth.
   - The administrator will need performance metrics data to determine resource utilization and bottlenecks. These systems and their workloads are changing constantly and information must be available to make good administrative decisions and to make changes, when needed, to keep the system running at the proper service level.

4. Reporting of Capacity and Performance data

   - The administrator must have a list of configured capacity and be able to view it based on related objects. For example, she or he must know how many logical devices exist on a group of disks and what server is using them. It must also be possible to view these logical disks in relationship to the application using them.
   - The administrator and architect need to understand the I/O profile and the combined workloads in relationship to a logical device, a port on any of the nodes in the I/O path, and the processor utilization for all nodes in the affected system. This information is essential for trend analysis and during performance problem

investigations. This data is difficult to collect because of the use of multi-vendor components in the data paths and their incompatible tools and reporting mechanisms.

- The CIO and architect will need actual performance data to show that service level agreements are being met. They will also want to see reports about the amount of capacity used and the amount still available, with trend lines indicating when additional capacity will need to be purchased.

While the virtualized resources such as disk to a virtual server help to mask the number of elements of concern, the administrator must have an understanding about this layer to be able to troubleshoot configuration conflicts and performance problems caused by sharing the resources. Without this understanding, an administrator cannot intelligently assigned resources to a project, and may have to adjust configurations as soon as they are put into production. Likewise, a performance problem cannot be investigated effectively without supporting data to corroborate or refute a theory or suspicion.

Feature Requirements for SRM Tool in Virtualization Layer

Configuration features.

The mapping of data paths is of highest importance and appears straightforward. However, it is actually one of the most difficult features to implement. Vendor-provided tool sets have this feature but only for their own equipment. With the virtualization layer end-to-end visibility is lost (Scully, 2010). The server vendors offer it to show and manage multi-path access to the disks and the views of these reports are from the host perspective and end at the entry point to the storage array. The storage vendors show the paths coming into the system and these reports are from the storage perspective. Unfortunately, they do not share the information for a common view of all of the data paths. Where multi-vendor environments are implemented, the problem of mapping the data paths becomes more complicated because the different vendor tools do not share configuration information and industry standards to share this information are inadequate (Standardization Efforts) to allow a continuous mapping of the data paths. Instead, the multiple tools output must be assembled manually, and storage administrators usually rely on Microsoft Excel spreadsheets since its data import wizards are flexible enough for many data formats. Ideally the management tools must collect the necessary information from heterogeneous elements and assemble them into a concise map for the administrator to clearly see the data path of storage resources.

In a storage area network the secure disk access is mandatory. As environments grow to hundreds or even thousands of ports, it is imperative that the security aspects of disk access can be managed efficiently. The administrator must have reliable information about all initiator and target ports and how they are logically connected. The basis for such information is the mapping data discussed above. The tool must provide relational information about the initiator and the disks they are allowed to see, and, from the storage port, which initiators are allowed to connect to individual disks. The tool must provide a report about stranded disks, or disks that do not have path redundancy.

Performance of all components are limited and whatever the limits are, they must be understood and incorporated into an IT solution design. The administrators must have information about these limits in order to balance workloads appropriately and to plan deployments of additional workloads. It is therefore important she or he has up-to-date views of workload patterns on the system. As is in mapping information, the collection of performance information and, more importantly, the subsequent correlation between components is a challenge, especially in heterogeneous environments. In the absence of this information, expansion plans are difficult to anchor in reliable data which can lead to incorrectly configured systems and a need for change. The fine tuning of a system to optimize performance is not unusual, but if major changes in the system are necessary then it can be disruptive to the business or, at the least burdensome on the administrative staff through additional work which could have been avoided with the proper tools.

Since storage virtualization advertises the use of heterogeneous equipment, customers are likely to take advantage of this feature. They will want to connect equipment from different vendors to the solution. The tools must be able to report on such configurations, however, none of the three vendors' solutions offers that capability today.

Storage virtualization layer.

The components of this layer are either a cluster of servers or a storage array itself. Since they are directly in the data paths, their uptime is critical and must be assured at all times. Solutions architects therefore go to great lengths to have redundant components in the nodes and, by clustering, to have at least two nodes operational at all times. This approach protects against node failures and allows the administrator to conduct maintenance on individual nodes. They also make sure that special events such as power failures cannot introduce errors in the data transmission. To that extent, the non-volatile memory in the cluster nodes are protected with battery power.

Administrators must manage these complex cluster configurations, maintain operational integrity, and balanced workloads at all times. The traditional tools and command sets in the operating system of these nodes are not adequate and must be supplemented with a tool that addresses the specific requirements of managing the storage virtualization setup. Such tool will provide the administrator with health-check information and alert the administrator when thresholds are crossed. It will allow the non-disruptive re-configuration of a setup to address temporary maintenance requirements, or permanent reconfiguration for performance balancing or expansions.

Performance features.

The components in the virtualization layer must be managed for maximum performance and low latency-to-data throughput. The administrator must be able to view the performance of each component and how the workloads affect them. The mapping information discussed earlier is, again, the basis to correlate performance metric with shared resources and helps determine which workload is the major contributor to a performance impact on any of the components of the system. The tool must allow for active performance management through workload balancing between ports in a node and among nodes in the cluster.

When an application exhibits a performance problem, the reports from this tool provide information about the location of the bottleneck and how it might be corrected by re-routing data paths to another part of the system. Without this information it is virtually impossible to pinpoint the problem and make informed recommendations to rectify the problem in a timely manner. An ongoing performance problem will frustrate customers and administrators alike and is emotionally stressful for application, database, storage, and network administrators (Bloom and Clark, 2009).

Performance information is also needed to plan for expansions and retirement of storage assets. The data in performance reports allows for the study of various situations that can help lead to determination of how resources can be re-configured to facilitate a continuous, flawless operation after the modifications are applied.

The CIO needs actual performance data to document whether service level agreements (SLA) were met and how closely they were met. This data insures that SLAs are within limits and defines what the margins of operation actually are. Such data can also be used to correlate to a business cycle and related workloads to the performance of the system.

Reporting features.

Fragmented tools also mean there are only fragmented reports available. Although each tool reports on elements in its domain, it cannot map a relationship to the rest of the environment. This shortcoming creates a major issue for administrators because they never have the complete perspective of a data path. This incomplete perspective gave rise to the common but unpopular use of spread sheets. While frowned upon, they are often the best option in a less-than-perfect situation. Because they required the manual process of assembling several reports into one, they are error prone and go out of date quickly. Some organizations have developed customized tools, but they are expensive to develop and maintain and, ironically, customers themselves solidify a vendor lock-in because these tools are not easily ported to and integrated with another vendor's products.

These observations highlight another critical requirement for efficient management tools: they must be able to project an accurate view into the virtualization layers through reports.

These reports must be generated for various objectives and audiences and address questions that arise at the respective levels of interest.

Management Reports

Managing staff needs to know that the systems are performing at the required service levels, that necessary changes have been applied or need to be scheduled, and that they are tracking trends on capacity, performance and bandwidth usage. The following reports are critical to management:

- General health of physical and virtual resources
- Capacity used, provisioned and available on equipment
- Error and failure reports
- Critical operational parameters are within the service level agreements
- Software and firmware are at supported levels
- Inventory lists for asset control

Administrator Reports

Administrators need access to detailed information in the context of the total system operation. This means the report must present related data elements, such as, where the virtual machine consumes storage space and which components are parts of its data path. The following reports are critical to administrators:

- Capacity provisioned and used by server and by virtual machine
- Ports used by physical and virtual machines
- Virtual machines sharing same data store and paths such as HBAs and SAN links.
- Characteristics of servers and virtual machines, including OS type, LAN information, and licenses
- Thresholds reached or exceeded for capacity on virtual volumes
- Thresholds reached or exceeded for iops or throughput on shared resources in data paths
- Thresholds reached or exceeded for iops or throughput on shared virtual volume
- Quality of Service configurations work correctly and levels are not exceeded
- Logs of all events are easily reviewed and critical errors are e-mailed immediately

These reports are an important aspect of effective storage management and cost savings. Storage virtualization makes these reports even more critical because the added level of abstraction removes visibility into the storage environments.

Chapter 5 – Impact of Storage Virtualization on Storage Management

As discussed previously in this paper, storage virtualization adds an abstraction layer between the physical storage hardware and the users of the storage space. This additional layer and all of its physical components must be managed from the procurement cycle to end of life, thereby introducing new tasks and responsibilities for administrators and offsetting some of the gains offered by storage virtualization. The complete solution is more difficult to plan and configure, but once implemented it makes ordinary storage provisioning tasks easier.

The ordinary and time consuming storage provisioning tasks can now be done by junior administrators. This is how operating expenses are reduced and is the opportunity of storage virtualization to contribute to reduced operating costs in the data center. This layer requires some changes to the established storage management procedures in order for potential savings to be fully realized.

Storage Provisioning and Allocation

The entire procedure in storage provisioning is taking longer, five instead of two steps. Steps 1, 2 and 3 are a setup procedure for the storage virtualization system. These steps require a high level of expertise. Vendor specific tools are used to make these configurations. These steps are done during initial setup and after more hardware are added to the configuration. The last two steps are the repetitive procedure applied when storage must be provisioning to users. It is at this stage where opportunities for cost savings may be realized. Another vendor tool is used to create this configuration even when the storage virtualization and storage arrays are form the same vendor.

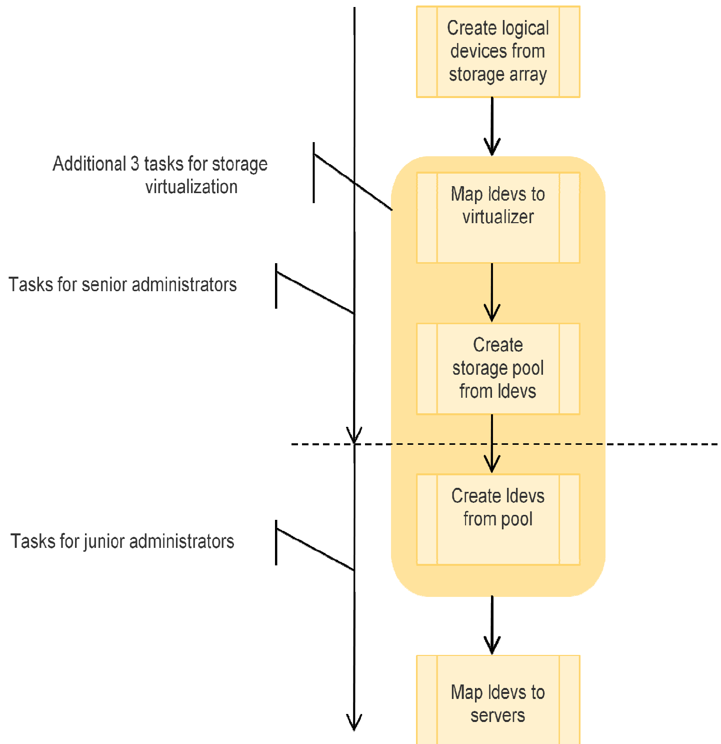

Figure 5 Storage Provisioning Process

The procedures can be broken up into the following high level steps as illustrated in Figure 5:

1) The senior level administrator sets up the storage pools, including:

   i) Creating logical disks on the storage array using element manager from storage vendor;

   ii) Allocating this space to the storage virtualizer (instead of servers);

   iii) Creating storage poola on the virtualization solution using element manager from virtualization vendor.

2) The junior administrator can be responsible for ordinary storage provisioning, including:

   i) Creating individual logical disks using element manager from the virtualization vendor;

ii) Allocating logical disks to servers.

The first two steps are the equivalent of the traditional steps of creating logical disks on the array and allocating them to a user. However, in this case the user is not a server but the storage virtualization system. Fortunately, these steps do not have to be done every time a server needs more space, but can be done when the array is first allocated to the storage virtualization system. These two steps only need to be recreated when storage capacity or bandwidth on the array is expanded. From that point forward, this procedure becomes a maintenance item for the administrators with capacity and performance monitoring and the monitoring of proper operation of its components.

In step 1) iii) the administrators need to create the pool with appropriate characteristics such as RAID level, number of logical devices, and cache allocation. The alerts must be setup to notify the administrators when the pool capacity is growing beyond a specified threshold in order to avoid running out of storage space in the pool. The pools are setup from logical devices provided by the arrays. These space segments are no different from devices assigned directly to servers in traditional storage provisioning without storage virtualization. However, they are larger in size to accommodate more manageable number for the benefit of the administrator. They are known by different names such as mdisks or DP Pool Volumes, but their purpose is the same. This step is done during initial setup of the pool with the element manager tool from the storage virtualization vendor. After completion of this step it becomes a maintenance item, adding to the responsibilities of the senior administrators. However the enhanced capabilities offer relief from the time-consuming and recurring tasks of assigning storage to users, as described in the last two steps.

The last two procedures can be assigned to junior administrators. These steps are the recurring procedures undertaken when users need storage space on servers. These two steps are also performed with the element manager tool from the storage virtualization vendor. Individual chunks of storage space are created and allocated to data paths leading to servers on the storage network. They are known by names like vdisks and DP volumes. In IT operations, these time-consuming tasks must be done frequently and promptly to serve the needs of the users. It is therefore a significant cost advantage when these tasks can be executed by less experienced administrators.

Procedures in steps 2 through 4 are the additional procedures necessary to provision with a storage virtualization solution. Even though they are the additional tasks in the storage provisioning procedure, they are performed infrequently. They are the enabler for a simpler procedure to ordinary storage provisioning. These changes in procedures ultimately allow for easier storage provisioning and result in operational cost savings.

Data Path Configuration

Data path configuration is a required setup procedure for storage virtualization. The storage virtualization system components are directly inserted into the data paths and must be zoned properly to have connectivity with resilient data access. This means that each logical disk must be available to all the nodes in the cluster and have at least one redundant access path. It is a simple rule but time-consuming to implement in large SAN environments. The components and their characteristics must be configured in the fibre channel switch element manager which is a separate tool from the storage element manager. In practical terms, this means transposing information from one tool to the other, a mundane and error-prone process. Since the tool cannot verify that resilient path configuration has been done properly it leaves the responsibility with the senior administrators. Third-party tools like SANScreen from Network Appliance is available to assist with this task, however, it means another element manager must be used to do one specific task (NetApp). The administrator must do this setup very carefully because a wrong or incomplete configuration can cause problems accessing data. Such problems might not manifest until a path goes off-line or a cluster node fails making a bad situation even worse.

Storage De-allocation and Retirement

The reverse process must be done when servers are decommissioned or when storage arrays are retired. With the server and storage sprawl becoming all too familiar to the administrators, this procedure is just as important as the allocation of storage and must be executed in an efficient and reliable manner.

1) A junior administrator can execute ordinary storage un-provisioning, including:
    i) De-allocate logical disks from servers;
    ii) Return logical disk into free storage pool;
    iii) Remove related zoning configuration in the SAN.

If it cannot be done efficiently and at the same time the server is removed, storage space will remain allocated to ghost servers. Stranded storage is a waste of resources and difficult to correct later due to the risks involved in removing storage space where historical information is no longer available. Worse, if it is de-allocated only partially it is nearly impossible for the administrators to safely remove remaining entries in the configuration tables. The same applies to configurations in the SAN where obsolete zones and aliases must be removed promptly.

Maintenance Items

These maintenance responsibilities and tasks create additional workloads for senior storage administrators. Even though some of the steps previously discussed are non-recurring in the process of allocating storage to users, the equipment and software must be managed to assure proper function of the system. The architect and senior administrator must maintain the components of the storage virtualization system. These tasks are imperative for reliable data access and include firmware and software level maintenance, capacity and performance monitoring, error-log reviews, and access control. The software update tasks require senior-level expertise and experience and must be coordinated with server and storage administrators to insure that firmware and software levels are compatible and supported by all vendors affected in the storage area network. Such tasks are time consuming to plan and execute and must be done during off-hours as dictated by typical risk management policy.

Configuration and Performance Reports

The setup of these storage virtualization solutions must be maintained for proper configurations and operations. However, because of the heterogeneous nature of storage virtualization, reports are available only for portions of the data paths because each vendor's tool can only report on the element from which it can retrieve information. As a result, storage administrators get fragments of reports and will need to find a way to assemble the pieces into a complete picture of data paths and storage configurations. Thus, it is time consuming to prepare reports about the state of the system. These reports are always suspect to accuracy and become obsolete as soon as modifications are made to the storage systems. Maps of allocated devices and their data paths, use and rate of growth are the basis for proactive management. Without them the administrators end up in more reactive mode situations which are disruptive and chaotic and go counter to established procedures. This type of environment in turn, raises the risk of human errors.

Tools on Data Center Level and Element Level

By wedging itself between the hosts and storage arrays, storage virtualization isolates the configuration information as well. The SRM tool must elevate its views from the lower element level to a higher data center level in order to to report the configuration relationships. Unfortunately, such tools cannot offer the extensive functionality of the element specific tools, at least not yet. Industry standards (Standardization Efforts) lack the details to exchange the necessary information between tools to make end-to-end management appear seamless. Today, the administrator has to use the individual vendor’s tools to see the map of the configuration. This requirement creates a disconnected picture of how storage resources are allocated, how much is used and by which servers. This situation creates the cumbersome workflows for storage administrators described above as they switch from one tool to another to allocate or de-allocate storage from a server, check and review configurations for consistency, or prepare end-to-end data paths reports. Such procedures are then error prone and more time consuming, adding to the operation expenses of storage solutions.

Regardless of the type of storage virtualization in place, in the network or on a storage controller, the attached storage still must be managed. The virtualization layer, however, is in addition to the existing storage array management chores. It can be argued that it has become easier manage storage and the added flexibility offered by the storage virtualization far outweighs the additional management requirements. Once a storage space is virtualized, it is managed as one big pool of storage capacity which can be assigned in appropriately smaller increments to servers throughout the enterprise. This advantage is the strength of the additional layer in management. In theory, once this space is under the control of the virtualization layer it can then be managed from one location with one tool. For regular capacity allocation, the administrators provision space from one of the pools to the server. Since this operation is the same regardless of which storage array is actually providing the space, it is a fairly routine procedure and, more importantly, does not change from one vendor and model of the array to another. Advanced functions like data replication for metro cluster or remote site can be done in the same layer. This means one place for the administrator to log-in, the same place to manage disk and to look for reports. This is the critical appeal for such products and the reason for its popularity with administrators. However, the capabilities of storage arrays and storage virtualization layers are far ahead of the tools provided and the administration of these new features is made more complicated because the tools do not provide support for all the new features or do so inadequately.

The Absolute Difference

The planning and implementation of storage virtualization solutions require a thorough knowledge of SAN and storage technologies. This level of expertise is available only from experienced and well trained staff and thus the solution is more expensive to implement. The return on this investment cannot be realized in the short term but will take time for the upfront configuration cost to be recovered over the long term. However, administrative efficiency, the number one promise of storage virtualization, can be realized immediately because the procedures to allocate and de-allocate storage from users are simpler and build on the work done during pool creation where the more difficult decisions are made. The tasks can therefore be assigned to junior administrators who do not need to have the depth and breadth of knowledge and education for the entire storage environment. This fact is the big advantage especially to large enterprises and builds on the realization that operational expenses of storage management can be lowered by shifting the time consuming and recurring tasks to junior staff.

Chapter 6 – Project History

This work has illustrated the evolution of storage systems and virtualization and the impact it had on storage administration. On the operational, level the net effort to administer data might not be lower than it was five or ten years ago, but without the improvements in storage technologies it would be many times more expensive to manage the exponentially higher data volumes and all the associated business requirements and government regulations. Storage administrators today manage much larger data volumes then they did five or ten years ago. Realistically, it would be impossible to provide the data services required without these new technologies. However, the more complex storage solutions require more sophisticated management tools and storage virtualization requires changes in operational procedures.

This fact has a profound impact on storage administration and documentation. Technology and process improvements are the only areas remaining that can be improved (Filks, 2010). New tools and industry standards are being developed and vendors are publishing APIs for their equipment to facilitate the sharing of management information. These advances will enable third-party software developers to address all layers in storage management. The new SRM tools will provide views at the data center level to give the CIO and staff the information they need to plan and operate a safe, secure, and reliable data storage environment and they will be able to do it in a heterogeneous environment.

Chapter 7 – Conclusions

Storage Virtualization offers features which allow an IT operation to come closer to a service provider of IT solutions. It is entirely feasible that the data management capability offered through storage virtualization is the enabler for the agile data center, where capacity and bandwidth can be adjusted to business requirements. This technology will allow the IT operation to deliver service as needed, at the level required and at the right time, rather than simply be a static cost center and charge its customers a fee based on fixed cost allocation. Business units require more flexibility in service levels and need it to be reflected in chargeback models. Since data management is a large portion of IT acquisition and operation costs, storage virtualization has come a long way to deliver a dynamic storage-level system.

At the same time, storage virtualization is a necessity for internal cloud computing. While internal cloud computing means different things to different people, the underlying need for an abstraction between the physical hardware and the logical elements for storage virtualization will position the architects for deployments of internal clouds.

Challenges Remain

The management and operation of large storage infrastructures remain a challenge. The existing element managers create fragmentation between components of the solutions and fail to integrate with tools at the data center level and with each other. The administrators are burdened by assembling of information to generate the reports in order to have complete and consistent information available to do their work (Bloom and Clark, 2009).

These challenges defer part of the promise of storage virtualization until tool integration is a reality. The demand is building to have better integration among tools that will drive storage array vendors and independent software vendors to work on combined solutions.

Tools Spanning the Data Center

When the tools are able to manage heterogeneous environments they will increase the storage administrators efficiency and the data centers agility. However, they must do so without limitations on integration and interoperability, otherwise their usefulness is relegated to the lowest common denominator. The administrators then must choose whether it is worthwhile to use the tool or simply use the individual vendor-provided tools, resorting to the status quo of storage administration. It is in the interest of the IT community to have SRM tools available that will span the entire storage infrastructure to help the customers exploit the potential of available technologies. Such tools will expose the end-to-end visibility and resource relationships that are so important in the operations of the agile data center. A centralized information repository would allow for the generation of unified views of configuration and performance data regardless of the brand and models in use at the SAN and storage level.

Standardization Efforts

The storage industry has acknowledged the challenge before it and has made diligent efforts to lessen the impact of this dilemma. Industry organizations like the Storage Networking Industry Association (SNIA) and the Distributed Management Task Force (DMTF) have developed standards to create a common management interface for storage products. This standardization makes it possible, at least in theory, to have one management tool regardless of the storage vendor, to perform storage provisioning and have the change applied to the entire I/O stack. Software developers have made some inroads into this area by leveraging the CIM and SMI-S protocols (Johanssen, 2009) however, they are hampered by the slow progress of the standards development, the depth and details of these standards, and by the slow implementation of the approved standards by the storage vendors. In fairness to the vendors, new feature developments often outrun the standards developments by two or more years. Any industry standard addressing cross-vendor issues relies on the lowest common denominator and so that while it has potential to provide greater functionality, it can only go as far and as fast as the implementers will allow.

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Glossary

CAPEX	Capital Expenditure, the cost of goods
CIM	Common Information Model
CIO	Chief Information Officer leads Information Technology department
CPU	Central Processing Unit
DMTF	Distributed Management Task Force
FC	Fibre Channel, a network protocol for Storage Area Networks
GUI	Graphical User Interface, what the user interacts with
HBA	Host Bus Adapter
I/O	Input/output data streams between server and storage
IP	Internet Protocol, the third layer in the protocol stack
IT	Information Technology, includes infrastructure and processes
JBOD	Just a bunch of disks, an enclosure with hard drives
LUN	Logical Unit, a logical disk device from a storage array
MTBF	Mean Time between Failures, time to expected failure of a component
OPEX	Operational Expenditure, the cost of running something
OS	Operating System
PCI	Peripheral Component Interconnect, a bus standard for computers
RAID	Redundant Array of Independent Disks
SAN	Storage Area Network
SLA	Service Level Agreement, between customer and IT department
SNIA	Storage Networking Industry Association
SRM	Storage Resource Management, tool to manage storage infrastructures

SVC	Storage Virtualization Controller, International Business Machines (IBM)
SVSP	SAN Virtualization Services Platform, Hewlett-Packard (HP)
UVM	Universal Volume Manager, Hitachi Data Systems (HDS)
WWN	World Wide Name, unique identifier for fibre channel devices