Storage Virtualization: Technology Overview

Summary

Virtualization presents a logical view of physical assets that is easier to administer and use than the actual physical objects. Read on to learn how virtualization is implemented in storage technology.

Table of Contents

Technology Basics
Technology Analysis
Business Use
Benefits and Risks
Technology Leaders
Insight

List Of Tables

Table 1: Pros and Cons of Virtualization Implementations
Table 2: Feature Comparison: Symmetric Appliances and Array Controllers

List Of Figures

Figure 1: Symmetrical and Asymmetrical Virtualization
Figure 2: Asymmetric Virtualization Will Enable the Next-Generation Monolith
Technology Basics

What Is Storage Virtualization?

The term “virtualization” appears frequently in today’s storage trade press, but seldom with any explanation of exactly what the term means. The concept sounds new and complicated, but actually it is only the current implementations that are new. The concept itself has been around for quite some time.

Virtualization refers to the presentation of a simple file, logical volume or other storage object (like a disk drive) to an application in such a way that allows the physical complexity of the storage to be hidden from both the storage administrator and the application. There are many examples of this in common use today:

- **Redundant array of independent disk (RAID)**—Disk arrays are often configured into RAID sets to either improve performance or provide fault tolerance for the data stored on the disks. It does this by grouping multiple disk drives together into arrays that the processor then views as one or more logical drives. This is a form of virtualization. Yet RAID has been around for over a decade. The term was originally coined in 1988 by a group of professors at the University of California at Berkeley, and the technique has been used and expanded on since then.

- **Volume Management**—Physical storage is usually sliced, diced or otherwise combined into different volume sizes using a volume manager. As with a RAID implementation, the application then sees one or more simple volumes that better meet the needs of the application where there really is a combination or division of physical volumes. This technique has also been around for quite some time.

- **Random access memory (RAM)**—The virtualization of memory is what allowed early programmers to write applications without consideration of a computer’s physical memory capacity.

- **File systems**—File systems have long presented the now-familiar view of files and folders while hiding the underlying block-level storage. Clustered file systems enable multiple servers to work on a common set of files. Distributed file systems can provide a single file system view across multiple storage boxes and servers. Directory mapping services create the appearance of a single file system or domain, even though the reality may be multiple file systems across multiple servers.

- **Virtual tape**—Virtual tape is intended to map disk or varied real-tape devices into legacy tape. Today, most virtual tape systems use primarily disk to speed up and simplify applications that the system believes are tape operations. Virtual tape can enable technology evolution without changing applications and can simplify overall tape management by consolidating tapes and speeding up operations.

The point is that virtualization is a technique for deploying technologies. Therefore, while virtualization seems to be the buzzword in the trade press today, users should not be fooled into thinking it is something new.

The primary focus of this report is block-level virtualization.

Storage Virtualization and the Storage Area Network (SAN)

Virtualization and SANs are not directly correlated, though it is hard to imagine any storage today without virtualization. While some very rudimentary systems (desktops and very entry level servers) actually mount the disk directly in the system, the vast majority of servers today employ some form of virtualization.
Storage Virtualization: Technology Overview

to abstract the physical storage into logical volumes. The purpose may be for data protection (that is, RAID) to improve performance (that is, striping) or simply to match the volume size requirements of the application.

Virtualization is imperative when building storage networks because in this environment the storage is generally being shared across multiple application servers. To facilitate the sharing, the physical volumes (RAID sets) in the arrays are broken up into smaller volumes to match the needs of the aggregated group of servers. The virtualization flexibility provided by a storage box or appliance in a SAN is the key attribute that allows effective SAN management.

There are two other virtualization features that are important when working with a SAN. The first is the ability to mask or hide volumes from servers that are not authorized to access those volumes, providing an additional level of security. The second is the ability to grow, volumes on the fly to meet the needs of individual servers. A variant being deployed by some vendors is to assign a very large logical volume to a server but only provisions physical storage as it is needed. More physical storage is then deployed as the application expands its use of the large volume. This technique hides the physical expansion from the application that sees only the original large assigned volume through the process.

Virtualization allows all the physical devices to be viewed and managed as if they were one large storage pool with no physical boundaries. “Stranded capacity” (the problem of having extra capacity sitting around inside a server) is no longer an issue. A RAID set that is pushing its capacity limits can be increased in size through the storage management software, using the extra capacity available on another device without any hardware reconfigurations at all.

Where Virtualization Is Implemented

Within a SAN environment, there are three general locations where virtualization can be employed: inside the host or application server, inside a well-featured disk array or inside an appliance within the SAN.

Host-based software is the oldest model, but since SANs are still a relatively new technology, host-based virtualization software (and in fact software in general) is generally not yet “SAN-aware.” That means that the host software must be re-architected to be able to recognize the distributed, shared environment of SANs. Software in the array has evolved in the past decade and is generally adaptable in current form to SAN environments, provided it does not have to span multiple storage arrays.

The disk array has evolved to become the primary location for RAID sets and volume virtualization today, especially within the SAN. In this model, the disk array holds the data and is therefore in a position to easily perform data-oriented actions, like snapshots or migrations, without first moving the data to an intermediate location. Its weakness today is that the logical volumes it creates and manages must be physically stored within the array itself. This means that when the disk array is full, any volumes that need to be expanded must be physically moved to another array.

The SAN appliance, which is essentially a server dedicated to and residing in the SAN, is the latest evolution in the virtualization story. It has the advantage of being able to see multiple arrays and hosts, but the disadvantage of holding neither the data nor the application. To work on data, the appliance first has to retrieve the data from the storage device. Then it does the work and returns the data to the storage device. Similarly, the appliance is not able to synchronize with the needs of the application without information found only in the application server.
Table 1: Pros and Cons of Virtualization Implementations

<table>
<thead>
<tr>
<th>Location</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Array-Based</td>
<td>• Close to data</td>
<td>• Needs re-architecting to span multiple arrays</td>
</tr>
<tr>
<td></td>
<td>• Can span hosts</td>
<td></td>
</tr>
<tr>
<td>Host-Based</td>
<td>• Close to the application</td>
<td>• Needs re-architecting for SAN/distributed-host</td>
</tr>
<tr>
<td></td>
<td>• Can span storage arrays</td>
<td>awareness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sensitive to changes in the server software stack</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Potentially difficult to deploy</td>
</tr>
<tr>
<td>Appliance-Based (emerging style)</td>
<td>• Can span storage arrays and hosts</td>
<td>• Close to nothing</td>
</tr>
<tr>
<td></td>
<td>• Best out-of-data path</td>
<td></td>
</tr>
</tbody>
</table>

Symmetrical and Asymmetrical Virtualization

Virtualization can be implemented either symmetrically or asymmetrically. In a symmetrical approach, the layers of abstraction and processing used by the virtualization technique are inserted directly into the data path. This approach is also referred to as “in band.” In an asymmetrical (or out-of-band) approach, the abstraction and processing control lies outside the data path. The following figure, “Symmetrical and Asymmetrical Virtualization,” shows the difference.

Figure 1: Symmetrical and Asymmetrical Virtualization
Storage Virtualization: Technology Overview

The primary advantage of the symmetrical approach is simplicity. Physical storage resources are allocated to one or more storage appliances (also called “domain managers”). Pooling is accomplished behind the appliances by virtualization using mapping tables, which store the links between logical volumes and actual physical addresses. These mapping tables sit inside the domain manager. Administrators can start with a single appliance and a minimum amount of physical disk and add practically any amount of any vendor’s storage until the system’s performance limits are reached. The primary disadvantage of the symmetrical approach is that each domain manager is one big potential single point of failure. And since every I/O must flow through this manager, its bandwidth is also a significant gating factor. Today, vendors are using clustering techniques to avoid both of these issues. The additional node(s) allows failover, but typically with much longer times than a dedicated array. Furthermore, multiple domain managers allow bandwidth to scale, though typically the virtualization in these products is stove-piped to the individual domain manager. As a result, it is difficult to pool storage across multiple domain managers.

Asymmetrical approaches are different. Their primary advantage is that they are not a single point-of-failure because the domain manager does not sit in the data path. As with the symmetrical approach, asymmetrical storage is virtualized through the use of mapping tables and organized into domains; however, these tables are then distributed throughout the SAN rather than sitting in the domain manager. Moreover, storage from an unlimited number of disk devices can be pooled without concern for bandwidth or addressing issues. The primary disadvantage of the asymmetrical approach is the need to distribute the maps to all the hosts and to provide a means of using them (that is, client software or hardware). Asymmetrical architectures are also generally more complex, involving more elements and requiring distributed system management approaches.

Symmetrical Virtualization Appliances

There are a number of startup companies that sell products that are inserted between the hosts and the external storage systems. These are generally referred to as “SAN virtualization appliances” or “SAN virtualization engines.” Some are a combination of hardware and software, while others are software only. Since these systems operate in the data path (in band or symmetrically), they are really just array controllers by another name. The following feature comparison clearly demonstrates that fact.

<table>
<thead>
<tr>
<th>Features</th>
<th>Symmetric Appliance</th>
<th>Array Controller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Located in the Data Path</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Aggregates Disks</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Supports RAID</td>
<td>Yes (also specifies RAID)</td>
<td>Yes</td>
</tr>
<tr>
<td>Slices Volumes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Has Redundancy and Failover</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>May Provide Cache</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>May Provide Point in Time Copy</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>May Provide Remote Replication</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>May Provide Support for Different Brands of Disks</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

The primary selling point for SAN virtualization appliances is that they help users implement and unify virtualization capability using their existing storage systems as well as any storage system purchased in the future. The key thing for users to look for when employing one of these solutions is that they do not introduce input/output (I/O) or throughput bottlenecks that make it impractical to continue using installed storage assets. When deploying virtualization products in new infrastructures, they should come with the
Storage Virtualization: Technology Overview

same degree of scalability and enterprise-class properties as the products they front-end. In performance-sensitive environments, for example, administrators should be aware that without enough cache, latency will always be added to the I/O. If the symmetrical appliance has write cache, it needs to have the same sophistication in algorithms and protection (batteries and mirrors, for example) as the arrays behind it do. Otherwise, the appliance may reduce data integrity and reliability. Also, although an appliance may support many interconnects, it is often likely that the internal processing power of the appliance will be the limiting factor on throughput. This means that the appliance is likely to be the bottleneck in configurations supporting multiple arrays behind one appliance. Some other questions that potential customers should ask include:

• Is the appliance explicitly supported by SAN management software?
• Does the proposed disk component have management tools and, if so, are they integrated/supported by the appliance and other software?

Administrators should also note that symmetrical virtualization appliances are being developed and marketed by smaller companies that take their products to market through original equipment manufacturers (OEMs); value-added resellers (VARs) or by a small, direct sales force. The OEM or VAR often takes on integration and other roles, but potential customers should be aware that these responsibilities can sometimes be left to the enterprise.

Simplifying Storage Management

Gartner has often used the word “monolith” or “monolithic” to describe high-end storage arrays from vendors like EMC, IBM, Hitachi Data Systems (HDS) and Storage Technology. The word alludes to the fact that these arrays are large enough to handle most applications in a single box and can scale capacity and performance/connectivity as the application needs grow. The most important value proposition of the monolithic boxes, however, has been that they provide a single storage entity to manage and can move and allocate any physical piece of storage to any host-side connection.

But the larger SANs deployed today, along with those that will be deployed in the future, have eclipsed even the largest of the monolithic arrays and require significant numbers of these boxes to meet capacity or performance requirements, or both. In other words, when the application is a large SAN, today’s “monolithic” arrays are actually “modular” arrays and can no longer provide single-box management behavior, which is still an important value proposition.

When multiple arrays are installed in a SAN, the switched fabric makes it possible to connect any physical storage to any host, but it does not inherently provide single-box management behavior. SAN management tools provided by most of the vendors allow all of the arrays and other components to be managed from a single console, but each array is still managed as a single entity. However, if the right form of virtualization were added as a key management layer and if the boundaries were eliminated, the resulting SAN and its storage would be manageable as a single entity (see figure “Asymmetric Virtualization Will Enable the Next-Generation Monolith”).

Figure 2: Asymmetric Virtualization Will Enable the Next-Generation Monolith
For this configuration to meet the definition of monolithic storage for large SAN deployments, the single-box management behavior must meet the total requirements of the SAN for performance scalability, capacity growth and higher-level Storage Area Management (SAM) software layers and functions. Single-box behavior also implies that the virtualization layer has the ability to mine and control the management tools found in each of the deployed storage arrays.

Virtualization is an important middle layer in most vendors’ visions for the future of SAM. These visions promise future storage management applications that can automate policy throughout an enterprise environment. Single-box behavior provided by virtualization for the entire storage pool in an enterprise SAN is key to simplifying the development and operation of these applications.

**Technology Analysis**

**Business Use**

Virtualization is a distributed technique found in many different layers of the software stack. It is required to simplify business operations and port applications, and it ultimately reduces management effort by allowing issues associated with installing, configuring, monitoring and managing physical storage to be isolated to a small group of well-trained storage administrators. It also eliminates the need for other IT personnel (such as application managers and systems managers) to be aware of, and trained on, the problems of managing physical storage.

In and of itself, virtualization is a key technique; however, it is always found with other management tools and physical constructs (such as storage networks) to accomplish the overall improvements and achieve management efficiency.

**Benefits and Risks**

As with any evolving technique, the benefits promised by virtualization are subject to a great deal of vendor hype. In particular, features and capabilities not really associated with virtualization are being attached to virtualization claims. Enterprises should therefore carefully sort out the claimed benefits of
Storage Virtualization: Technology Overview

products to make sure that they are not being implemented redundantly (in, for instance, an appliance or a storage box) and that they don’t create more management complexity to get the implied benefit.

At the most basic level, the benefits of virtualization fall into two categories: flexibility and quality of service (QOS). Flexibility is important because it allows the storage administrator to build and maintain volumes that specifically meet the ongoing needs of the enterprise’s applications. Administrators are no longer constrained by the physical limits of the disk arrays and can build the quantity and size volumes that they require. Furthermore, virtualization offers dynamic volume change capability. Administrators no longer have to guess what each application’s requirements will be down the road and then either live with the results of their estimates or undergo time-consuming, disruptive and expensive re-configurations. With today’s virtualization capabilities, administrators can make transparent changes in volume size within an array, and it is expected that in the future it will be possible to build volumes across the boundaries of arrays and vendors. QOS encompasses the areas of availability, performance and cost to an application. Virtualization is intended to provide the right mix of these elements by:

- Eliminating the stranded capacity problem associated with nonvirtualized arrays (increasing use).
- Avoiding “hot spindles” (drives experiencing intense I/O loads either because of frequent access requests or because the RAID level assigned to the drive increases the drive’s workload) and simplifying the process of redeploying capacity when the needs of an application change (improving performance).
- Simplifying the addressing of storage volumes (increasing flexibility).
- Reducing downtime, since changes are made through storage management tools at the virtual level rather than at the physical level (increasing availability).
- Reducing both staffing and training costs as more capacity can be managed on fewer storage devices (reducing cost).

The challenges related to virtualization are associated with the extra layers of software and potentially with extra hardware as well which threaten to increase complexity. The extra code and components can potentially reduce reliability. If the virtualization is in the data path, for example, the appliance becomes both a single point of failure and a potential limit to performance. Finally, the role that virtualization plays in the data path in hiding the physical complexity from the application can get in the way of manageability.

Technology Leaders

Vendors that provide symmetrical virtualization solutions (disks integrated with controller) include:

- 3PARdata, Inc. (Fremont, California)
- DataDirect Networks (Chatsworth, California)
- Dell Computer Corp. (Round Rock, Texas)
- Dot Hill Systems Corp. (Carlsbad, California)
- EMC Corporation (Hopkinton, Massachusetts)
- EqualLogic, Inc. (Nashua, NH)
- Fujitsu Technology Solutions Inc. (Sunnyvale, California)
- Hewlett-Packard (Palo Alto, California)
Storage Virtualization: Technology Overview

- Hitachi Data Systems Corp. (Santa Clara, California)
- IBM Corp. (Armonk, New York)
- LSI Logic Corp. (Milpitas, California)
- Network Appliance (Sunnyvale, California)
- Storage Technology Corp. (Louisville, Colorado)
- Sun Microsystems Inc. (Palo Alto, California)
- XIOtech Corp. (Eden Prairie, Minnesota)

Vendors that provide symmetrical virtualization appliances (hardware integration required by channel or user) include:

- DataCore Software Corp. (Ft. Lauderdale, Florida)
- FalconStor Software Inc. (Melville, New York)
- Fujitsu Softek (Sunnyvale, California)
- Hewlett-Packard (Palo Alto, California)
- IBM Corp. (Armonk, New York)
- Veritas Software (Mountain View, California)
- Vicom Systems Inc. (Fremont, California)

Vendors that provide asymmetrical virtualization hardware solutions include:

- StorAge Networks (Israel)

Insight

Virtualization is an important technique that exists in arrays, host software and, increasingly, in SAN appliances. Its principle benefit is simplifying presentation of volumes to applications while hiding more complex physical configurations used to improve performance, availability, manageability and QOS. Users evaluating virtualization offerings should look at the flexibility provided in creating and managing volumes, and for the ability to span array and server boundaries with the result.