Disk Array Storage: Overview

Summary

Today’s disk arrays offer highly available, fault-tolerant storage for a variety of markets, using features like redundant components, battery backup, remote copy facilities and RAID implementations.

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Aggressive storage strategies aren't just for data centers anymore. Today, small and midsize businesses also place a high priority on storage strategies, both in terms of ensuring that their capacity requirements are met and that the data that is stored is protected. With more and more data being stored, and with information in general taking on an increasingly more important role in business operations, protecting the data and ensuring that it is always (or nearly always) available to the user are paramount concerns. As a result, vendors are on an ongoing quest to develop more reliable and cost-effective disk-array storage solutions for all classes of users.

There are several features that customers can look for which contribute to increased performance, fault tolerance and high availability. They include the following:

- **Redundant Components** — A second (or sometimes more) backup component incorporated into a disk array by the manufacturer that will take over in the event of a hardware failure in the primary part. These backup components can function in one of two ways. They may sit idle, waiting for a failure to occur before being activated (hot-spare standby drives, for example), or they may operate alongside the primary part to improve performance under normal operating conditions while at the same time possessing the capability to take over completely and keep the system up and running if the primary part fails (redundant array of independent disks [RAID] controllers, for example). Common redundant components are RAID controllers, disk drives, cooling fans and power supplies.

- **Hot-Swap Capability** — The ability to remove and replace a component without shutting down the entire system. Some of the components that can be hot-swappable include disk drives, power supplies and cooling fans.

- **Hot-Spare Standby Drives** — Extra drives installed in the disk array that automatically come online in the event of a disk failure. When certain RAID technologies are implemented, the contents of the failed drive can then be automatically reconstructed, restoring the disk array to full functionality without any operator intervention.

- **Battery Backed-Up Cache** — Battery power that protects any data that happens to be in cache at the time of a power interruption.

- **Mirrored Cache** — The process of mirroring the write data in cache as a further method of data protection.

- **Cache or Disk Scrubbing** — A method of proactively testing data for errors even when the cache or disk is inactive, so that problems can be detected before they can disrupt data flow.

- **Full-System Battery Backup** — Allows the disk array to remain operational in the event of a power failure, at least long enough for data in cache to be destaged to disk and for the system to complete a graceful shutdown. This feature is something that a few vendors supply standard while others support via an optional uninterrupted power supply (UPS).

- **Integrated Controllers** — A crucial element in the success of RAID technology, since some of the more complicated levels require more complex controllers.

- **Automatic Failover** — An active/active RAID controller design whereby there is automatic switching capability from one RAID controller to another in the event of a failure, providing both failover and load balancing within the disk array.
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- **Alternate Pathing** — The ability to automatically switch between input/output (I/O) paths in the event of a failure in one of the paths.

- **Phone-Home Capability** — A disk array’s ability to contact its manufacturer directly if a component within the disk array exceeds certain preset thresholds, so that reparative action can be taken before the component actually fails. This contact is made automatically via modem without the storage administrator’s intervention, though an alert is also generated to notify him or her.

- **Environmental Monitoring** — A system of sensors that monitors physical conditions within the array hardware itself (such as power and temperature) and that sends an alert through the storage management software if any of the preset thresholds are exceeded, indicating a possible problem.

- **Nondisruptive Microcode Updates or Replacements** — The ability to update or replace the RAID controller microcode without having to shut down the disk array. This feature is supported on most midrange and high-end disk arrays, but is generally not guaranteed.

- **Point-in-Time Copy** — The ability to make a copy of selected data on the disk array extremely quickly so that the downtime associated with doing a backup is minimized. Each manufacturer implements this rapid data duplication function a little differently, and each has its own name for the function (“SnapShot” for StorageTek, “FlashCopy” for IBM, “TimeFinder” for EMC, “Business Copy” for Hewlett-Packard, “ShadowImage” for Hitachi Data Systems [HDS]). Traditional point-in-time copy techniques require that disk space equal to the size of the volume to be copied be reserved in advance. However, some manufacturers offer a virtual implementation whereby the target volume is a new virtual disk that initially shares the same virtual directory map entries as the original volume. Thus, capacity need not be reserved in advance. Additional disk space is required only if the original is modified.

- **Remote Mirroring** — The process of copying data to a second disk array, often housed in a separate location from the originating disk array. This functionality is most frequently used for disaster recovery purposes, though other tasks, such as data center migration, can be managed this way as well. Remote mirroring can be accomplished synchronously, asynchronously or semisynchronously. Synchronous mirroring requires that the write operation be successfully completed at both the primary and the remote site before the I/O is considered complete. Asynchronous mirroring allows the remote write to be completed independently of the write to the primary disk array. The benefit is that the primary disk array is available to process the next read or write command sooner. The disadvantage is that the remote-site data is always slightly less current than when using synchronous mirroring. Semisynchronous mirroring provides sort of a middle ground. It functions similarly to asynchronous mirroring, but with a specific (and usually short) limit to how far the asynchronous mirroring can get behind.

- **Capacity on Demand** — A service available to storage customers whereby the storage manufacturer ships more storage capacity in a disk array (and sometimes more cache memory or other components as well) than the customer initially purchased with the understanding that the additional capacity can be “turned on” when needed by the customer. The purpose is to minimize delays associated with ordering, shipping and installing additional resources by making them available on demand. Vendors that provide this service generally charge an upfront fee for shipping the unavailable capacity. They either require a manufacturer “key” to activate the unused capacity, or they have the capability to monitor when the capacity starts to be used and can generate a bill from there.
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In addition, many disk array vendors differentiate their products from the competition by their storage management software offerings, as well as by a choice of interface support and user-configurable RAID levels.

Storage Management Software

Storage management software covers a wide range of functions. These range from file system and volume manager on the server down to the element manager that sits on the disk array, which allows for the configuration and health monitoring of the device. Gartner divides the storage management software market into three segments:

- **Storage Infrastructure Products** — Provide basic data organization functions, such as file systems, volume management and replication, ensuring data integrity and availability by offering fast failure recovery and data redundancy.

- **Data Management Products** — Includes backup, restore, archive and hierarchical storage management (HSM) tools.

- **Enterprise Storage Resource Management** — Products providing the ability to manage various storage resources on the network, including magnetic disk and bulk media, such as tape and optical media. These applications manage properties of physical and logical storage resources; for instance, media health, availability, space loading, performance, connectivity and use. They also allow for central administration and automated management of a network’s storage resources, which may include hubs and switches as well as storage devices. Also included in this segment are products that manage and distribute corporate storage-management policies and licenses.

All disk arrays come with a software tool that allows for the management of the array. In its simplest form, disk resource management software performs three functions. First, it provides the necessary tools to create, change and delete volumes. Second, the tool helps system administrators to monitor the storage capacity and usage trends so that they can respond to any bottlenecks that occur. And third, it enables them to quickly identify any hardware failures or other problems that arise which could affect the performance or integrity of the disk array. Optional advanced features, such as predictive failure notification, point-in-time copy, remote mirroring and phone-home capability, have been added to increase the reliability, availability and manageability of the storage system. As the market has evolved, and as the size and number of arrays at a customer site have increased, the basic management tools have evolved as well. Older tools used command lines to communicate. Today, tools use more visual displays and are wizard-driven to simplify their use. Array vendors are also offering software that will manage multiple arrays from a single console and that provide links into other management tools as well. As the storage environment expands beyond direct-attached to include fabric-attached storage (FAS) that is shared across heterogeneous application server environments, storage resource management (SRM) tools must now manage multiple types of storage devices, including the storage networking devices.

In order for software vendors to gain access to information about a storage device and to send information to that device for management purposes, the device must be engineered to provide that support. At a very basic level, most devices provide a command line interface (CLI) for users and software developers to use to manage the device. This scripting interface can access exposed device features to perform the basic functions described above. If the vendor has implemented features for command acknowledgement for successful and error results, the CLI can also be used for automating device management. But application developers wanted a way to communicate with the device using a standard development language. Vendor-supplied application programming interfaces (APIs) and standard interfaces are designed to meet that need. A management standard protocol called Simple Network
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Management Protocol (SNMP) is used to request and retrieve the data from a management information base (MIB). Storage-device vendors who want to encourage software development often provide more robust links into their devices than simple CLI scripting and support for SNMP and MIBs. This support is provided by an API that allows the programmer to use standard programming languages, such as C, C++, Java or Extensible Markup Language (XML), to receive and send information to the device. Storage device vendors who have delivered APIs have been able to capture a larger percent of the independent software vendor (ISV) resources to date and have devices that are supported by a wider range of management software.

As the need for robust storage management tools evolves, there is a move in the industry to rethink the standards used to provide information about storage devices. The goal is to increase the information that is widely available for management purposes and to make it available in a way that better supports software development. The network and systems management space has defined the Common Information Model (CIM), a schema-based model to enable the relationship management of objects in the management environment. Since storage will eventually need to be managed in the context of the total environment, which includes networking and servers, the storage industry through the Storage Networking Industry Association (SNIA) is defining a specification to add storage objects to the CIM model. It is encouraging all device vendors to develop CIM providers that provide information as defined in the specification. Version 1.0 of the CIM storage specification was submitted for standards review and adoption in April 2003.

RAID

The term “redundant array of independent (or inexpensive) disks” and its associated acronym “RAID” were originally coined in 1988 in papers written by Professors Gibson, Katz and Patterson of the University of California (UC) at Berkeley. It presented a relatively simple way to increase performance or fault tolerance by grouping multiple small form-factor disk drives together into arrays that the processor would view as a single logical drive. Although originally used in high-end, mainframe and minicomputer environments, RAID technology has also been deployed in the open-systems (Unix, Windows NT/2000 and Novell NetWare) environment since 1990. In addition, several vendors have introduced high-end enterprise RAID disk arrays that support open systems in a heterogeneous server environment.

RAID arrays are not to be confused with storage systems configured as just a bunch of disks (JBOD). Like RAID arrays, JBOD storage consists of a group of drives, but they do not use any form of hardware- or software-based RAID technology to manage the data movement and so do nothing to address data protection or recovery.

The original UC Berkeley papers defined five levels of RAID to identify and classify various disk-array architectures (RAID 1 through RAID 5). Since then, one more level was officially added (RAID 6), and several other, unofficial implementations have been defined, including a proprietary implementation referred to as RAID 7, a nonredundant implementation called RAID 0 and several hybrid implementations:

- **RAID 0** — Also called “striping,” RAID 0 refers to an array where data blocks are split and written (or “striped”) across multiple disks simultaneously. Technically, it is not a RAID level at all, because it offers no redundancy or fault tolerance. However, because of the improved I/O performance it provides, it is a popular implementation for disk arrays where data protection is not a requirement.

- **RAID 1** — Also known as “disk mirroring,” RAID 1 refers to an array where the exact same data is stored on two drives simultaneously, forming a mirrored pair that presents itself to the host computer as a single drive.
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- **RAID 2** — This level of RAID provides the user with a parallel array using Hamming error correction code (ECC), which detect and correct bit-level errors in computing data, rather than 100 percent duplication. Data is striped in bit increments across an array of disks, and multiple check disks are required to detect and correct any errors. Because RAID 2 has a high CPU overhead for the host system, and because disk drives now include built-in error detection and correction, which eliminates any benefits of this feature, RAID 2 is not used in modern-day RAID-based disk arrays.

- **RAID 3** — RAID 3 provides users with a parallel array solution similar to RAID 2, but using parity, based on an Exclusive OR (XOR) algorithm, instead of ECC for fault tolerance. Each record of data is striped across all but one of the drives in the array, with the last drive reserved for storing the parity data that can be used to recover lost data in the event of a drive failure.

- **RAID 4** — Like RAID 3, RAID 4 provides a parallel array solution using data striping and a separate drive to store parity information. However, in RAID 4 the stripes are larger (data is interleaved between disks on a sector level rather than at the bit level), so that entire records typically fit on a single drive. Since RAID 4 offers no overhead advantage over RAID 5, and since RAID 5 offers faster write performance along with the increased read performance, RAID 5 is the preferred implementation.

- **RAID 5** — Also called a Rotating Parity Array, RAID 5 stripes data across all available disks in the array and uses parity as a method of recovering any data lost due to a drive failure. However, in RAID 5, the parity data is not stored all on one dedicated drive. Instead, it is distributed like the actual data, across all the drives in the array.

- **RAID 6** — Not one of the original RAID levels defined by the Berkeley team, but added by Berkeley professors in a 1989 paper, RAID 6 provides dual redundancy. Each disk in a RAID 6 array has two sections set aside for storing parity data, and the parity information is computed in two different ways, which are then stored separately in the array.

- **RAID 7** — RAID 7, a proprietary solution trademarked by Storage Computer Corporation, uses an asynchronous architecture to allow drive heads to move independently of each other and to allow drives to be accessed independently (since I/O data paths operate asynchronously as well). Multiple levels of cache are also used to facilitate multiple simultaneous operations.

**Hybrid Levels of RAID**

As the name implies, hybrid RAID levels are implementations that result from combining two of the above RAID levels in the same disk array. This “nested” approach allows users to improve either capacity or performance while still attaining the desired level of fault tolerance. When implementing a multinested RAID approach, it is important to understand which of the two RAID levels is being configured first. RAID 0+1, for example, is not the same as RAID 1+0. One performs the striping function first and then mirrors the two arrays, while the other sets up pairs of mirrored disks and then stripes data across the pairs, with different effects on performance and fault tolerance. The four hybrid RAID levels are:

- **RAID 1+0** (a.k.a. RAID 10): Combines striping with mirroring.
- **RAID 3+0** (a.k.a. RAID 30 or RAID 53): Combines striping and RAID 3-style parity.
- **RAID 5+0** (a.k.a. RAID 50): Combines striping and rotating parity.
- **RAID 1+5** (a.k.a. RAID 15): Combines mirroring and rotating parity.

While RAID implementations can vastly improve the fault tolerance of a disk-array storage solution by protecting against data loss due to a disk-drive failure within the array, it is important to also note what
they cannot do. RAID does not protect against disk-controller failure, for example. Nor does it guard against user errors (such as accidental deletion), virus infection or natural disasters (such as flood, fire or earthquake). For those situations when an entire disk-array storage solution — or, worse, an entire network — crashes, additional backup solutions must be employed. Backup copies of data should be made on removable media (such as tape) and stored at an off-site location to ensure recovery capability. In addition, vendors have developed software applications that assist in managing the backup process and that will speed up the disaster recovery process.

Hardware or Software RAID

RAID protection can be incorporated into a disk array using one of two methods. The most common is hardware-based RAID, which uses storage processors to handle RAID overhead, such as calculating checksums and directing file I/O to the correct disk. Hardware-based RAID implementations typically use a dedicated disk-array controller board, thereby accomplishing RAID functions separately from the applications processor.

The other option is a software-based (also called host-based) approach. Software-based RAID arrays pass the overhead on to the host CPU, requiring it to bear the burden of generating parity information and managing recovery operations and thereby decreasing available bandwidth. Software-based RAID implementations are characterized as direct-attached storage managed by host-based software disk mirroring (RAID 1) or software parity RAID (RAID 5) to prevent data loss in the event of a disk failure. Software-based RAID typically costs less than hardware-based RAID because it does not include the cost of the storage processor. However, declining disk prices, coupled with new lower-cost RAID controller technology, have contributed to increased sales of hardware-based RAID solutions.

Technology Analysis

Storage models continue to evolve as business needs change. The traditional storage model, called “direct attached” or “server attached” storage, is achieved by attaching storage peripherals directly to a server. Software on the server allows other users on the network to access the data in storage, but it is all controlled by that one server and therefore requires the use of valuable server-processor cycles to function.

As networking became more popular and storage needs grew, however, a new storage model, called network-attached storage (NAS), evolved. Here, storage devices are plugged directly into the network via a NAS device (also known as a “NAS appliance” or “NAS head”) rather than being tied to a specific server, allowing storage resources to be manipulated (added, removed, reconfigured) without interrupting operations on the network or any individual server. These NAS devices embody many characteristics of the classic file server, but are stripped of all software features and hardware components except those related to file sharing. Relieved of all other duties, a NAS device can be extremely simple to install and configure. They typically do not come with monitor or keyboard and are configured and managed remotely either through a Web browser or a utility supplied by the vendor. NAS devices make their internal operating system transparent to the end user. Although they run operating systems, such as Linux, Windows or proprietary software, they do not require any manual interaction with these environments.

Once connected to the network, NAS devices emulate standard network file servers. The file systems delivered to the network by a NAS device can be either accessed directly by client computers or mounted by application servers. Multiple servers or clients can access a NAS storage volume simultaneously. While NAS devices operate as independent servers, they can leverage the authentication and authorization capabilities of established servers on the network, eliminating the need to recreate user accounts and access control lists.
A third model is the storage area network (SAN), which offers storage users an alternative to the direct-attached or NAS storage architectures. In the SAN, storage is centralized into its own separate network, front-ended by a thin server with storage management software so that any server on the network can reach any data in storage, and backups can be done without using server cycles and affecting network performance. SANs move data efficiently without adding to the load of the communications network.

SANs provide block I/O services between computer systems and storage elements, and among storage elements connected in a network. These services may support file systems on SAN-attached servers directly, or they may support file systems for servers that provide file services over the communications network. Currently, nearly all SANs are implemented with a dedicated Fibre Channel network, although other networking technology is emerging. SANs provide physical connections between devices on the network and a management layer for organizing data transfer among the connected devices. SANs enable backup to attached tape systems without connection to the communications network; data movement may pass through a server. Fibre Channel provides its own low latency and loss-free transmission protocol, and is now implemented primarily in switched fabric networks. Support for the legacy Fibre Channel-Arbitrated Loop (FC-AL) protocol is provided by loop switches that support the protocol but that provide the bandwidth aggregation characteristic of switch products.

The key principle of the SAN involves the offloading of data transfers from the communications network. In a SAN environment, many data operations can be accomplished without having to traverse the LAN. Data communications protocols, such as Ethernet and Internet Protocol (IP), introduce significant overhead in the transmission, while Fibre Channel technologies dispatch large amounts of data with great efficiency. The SAN is transparent to network end users, so client computers and Web users are unaware of the existence of the back-end SAN architecture. From the perspective of users on the LAN, there are no outward signs to indicate that the network servers rely on a SAN for access to storage devices.

Another technology that has emerged over the last year is Internet Small Computer Systems Interface (iSCSI), which provides block I/O services over Ethernet and IP networks. Designed to leverage established IP network infrastructure, iSCSI expects to combine the extended connectivity of IP networks with the lower cost of components to achieve a suitable level of performance initially lower than that of Fibre Channel. In addition, two other technologies, Internet Fibre Channel Protocol (iFCP) and Fibre Channel over IP (FCIP), are emerging to provide transport of data blocks between Fibre Channel devices over the IP infrastructure. Differing in detail, both are capable of providing extended links between Fibre Channel devices. Each technology employing IP storage may implement the TCP/IP stack in software, or it may offer improved performance with the use of hardware accelerated TCP/IP offload engines to create a storage network rather than the Fibre Channel technologies on which current SANs are based. iSCSI leverages established network technologies and products instead of requiring a separate SAN infrastructure. This approach was originally promoted by Nishan Systems, a San Jose, California-based company that offers storage over IP (SoIP) switches, but is now also being targeted by several other companies, such as Network Appliance and storage startup EqualLogic, as well. With iSCSI, servers, tape libraries and disk storage arrays connect through special adapters and switches that deliver data without the inefficiencies associated with the full TCP/IP stack. Its promoters hope that iSCSI will achieve greater interoperability and acceptance through the use of widely adopted protocols, like Gigabit Ethernet and IP, rather than Fibre Channel.

Interface Support

Host-side connectivity on today’s disk arrays is most commonly provided via Fibre Channel in the open-systems market, though SCSI connections are also used in lower-end models or as a way to build added flexibility into a disk-array solution. As mentioned above, Fibre Channel connectivity is most commonly implemented in switched fabric networks in a SAN, while support for FC-AL is provided by loop switches.
In the mainframe environment, Enterprise Systems Connection (ESCON) and Fiber Connectivity (FICON) interfaces are used.

The other side of the disk-array connectivity picture is the “target,” or “disk interface.” Mass storage peripherals used to rely primarily on the SCSI-2 interface; however, that is now evolving as well. The SCSI standard has been enhanced to include Ultra SCSI (SCSI-3), with data transfer rates up to 320 megabytes per second. The high-speed FC-AL interface, which is deemed especially effective for disk drives because it distributes switch logic down to the individual device level, is also now commonly available, with 2 Gbps Fibre Channel rapidly becoming the standard for higher-end solutions. Other up-and-coming back-end interfaces include Serial Advanced Technology Attachment (SATA) and Serial Attached SCSI (SAS), two technologies that transmit signals serially rather than in multiple parallel streams. SATA enables Advanced Technology Attachment (ATA) -based disk storage to support a point-to-point architecture, longer cable lengths, hot-plug capability and enclosure management among other features. SAS, the follow-on to parallel SCSI, provides point-to-point serial connections, dual-ported connections, an SATA-compatible connector and improved drive addressability among other features.

Business Use

Many businesses are currently feeling the effects of a struggling economy and the uncertainty of worldwide geopolitical events, and the storage industry is no exception. According to Gartner Dataquest, the total worldwide factory revenue forecast for direct-attached storage (DAS) and FAS, which reached $23.9 billion in 2001, declined in 2002 and is expected to fall further in 2003 and 2004. Gartner Dataquest does not anticipate positive revenue growth in the disk-storage market sector until 2006.

During this period, user demand will continue to focus on reliability and availability issues as customers seek to extend the life of their product investments. High-availability features, which used to be strictly an enterprise-level disk-array phenomenon, are now finding their way into midrange storage products as well, as vendors produce more cost-effective storage solutions for all classes of users. Competition has specifically increased in the high-end disk-array market. Disk arrays now come in a variety of capacity ranges to suit the needs of most businesses, theoretically scaling to over 100TB (though the average shipping configurations are significantly less), and with RAID costs dropping every year, this trend is expected to continue.

Standards

In August 1992, the RAID Advisory Board (RAB) was founded to help with the understanding and use of RAID technology. To clear up RAID Level misperceptions, the board published a book containing the RAB-endorsed RAID Level definitions. Since then, RAB has gone on to establish storage-system guidelines based on Extended Data Availability and Protection (EDAP) attributes for both disk systems and array controllers.

The EDAP standards are made up of 20 criteria that have been summarized into three basic classifications that indicate the degree to which a system can protect itself from data loss and maintain data accessibility under a number of specified failure conditions. Each category can be applied to either disk systems or array controllers, and each includes one or two enhancement variations designated by plus signs. Vendors have the option of classifying their products according to the EDAP categories, and the RAB verifies those classifications.

The three EDAP classifications for disk systems are as follows:

- Failure-Resistant Disk System (FRDS and FRDS+) — The lowest level of EDAP, FRDS indicates that the disk system can protect against loss of data or data unavailability due to disk failure.
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- **Failure-Tolerant Disk System (FTDS, FTDS+ and FTDS++)** — A step up from the Fault-Resistant criteria, FTDS and its variations guarantee protection against loss of data or data unavailability due to the failure of any single component of the disk system, not just the disks themselves. That includes the controller, power supply and cache.

- **Disaster-Tolerant Disk System (DTDS and DTDS+)** — The highest level of EDAP, DTDS includes all the previous features and adds the ability to protect against loss of data or data unavailability due to the failure of one disk system consisting of two or more zones that are at least one kilometer apart (DTDS) or at least 10 kilometers apart (DTDS+).

**Technology Leaders**

Leaders in the disk-array storage market include Dell, EMC, Hewlett-Packard, Hitachi Data Systems, IBM, LSI Logic, Network Appliance, Storage Technology Corp. and Sun Microsystems.

**Dell Computer Corporation (Round Rock, Texas)**

Dell offers two lines of disk-array products for the midrange open-systems market — one as part of a strategic alliance agreement with EMC (cobranding and reselling the CLARiiON products) and the other its own PowerVault line for the NAS market.

**EMC Corp. (Hopkinton, Massachusetts)**

EMC offers products for both mainframe and open-systems markets, with the CLARiiON disk arrays for the midrange and lower high-end market, the Symmetrix Series for the high end, the Celerra File Server (based on Symmetrix) and the Celerra NS600 (based on CLARiiON) for the NAS market. Its product lines include both storage hardware and the storage management software needed to move data across heterogeneous environments.

**Hewlett-Packard Company (Palo Alto, California)**

The merger agreement between Hewlett-Packard and Compaq was finalized in May 2002, and the effort to merge the two vendors’ product lines began. Today the company offers the StorageWorks Modular Storage Array (MSA) 1000 at the entry-level, the StorageWorks Enterprise Virtual Array for the midrange and midrange enterprise markets, and the StorageWorks XP Series for the high-end markets. The StorageWorks XP Series is sourced from Hitachi Ltd./Hitachi Data Systems. The StorageWorks Virtual Array Series fills out the low-end and midrange product lines.

**Hitachi Data Systems (Santa Clara, California)**

HDS offers disk-array storage solutions for midrange and enterprise-class heterogeneous environments. Its Thunder product line is targeted for midrange open-systems environments, and its Lightning product line is targeted at the high end, supporting both mainframe and open-systems platforms. Most recently, HDS added two new high-end disk arrays with virtualization capabilities to its Lightning line (May 2002). These new products are included in the partner agreements that Hitachi Ltd./HDS has long had with both Hewlett-Packard and Sun Microsystems. Hewlett-Packard original equipment manufactures (OEMs) the Lightning products, while Sun has a distributor agreement.

**IBM (Armonk, New York)**

IBM has long participated in the storage market, with everything from disk drives and disk-array products to tape-drive and automation products. It conducts extensive R&D and provides products designed to meet all levels of business need. In the disk-array arena, IBM offers products for both open systems and the enterprise and from the entry level to the data center, including the Enterprise Storage Server for the
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high-end market, the FAS9T Series for the midrange enterprise market, the 7133 Serial Disk System for host-attached storage in the midrange market (which IBM sources from LSI Logic) or as an expansion cabinet for the Enterprise Storage Server, and the 2104 Expandable Storage Plus at the low end.

LSI Logic (Milpitas, CA)

LSI Logic sells Fibre Channel storage systems for low-end and midrange open-systems environments, including the 5884-based, 4884-based, 2882-based and 2772-based Storage Systems. In addition, the company sources its products to other manufacturers who then sell them under their own brand names.

Network Appliance (Sunnyvale, California)

Network Appliance (NetApp) offers a series of NAS products, including the FAS900 Series of Enterprise Servers, and the F800 Series of filers for the enterprise and workgroup markets. It also offers nearline storage solutions, including the NearStore R150 and the NearStore R100.

Storage Technology Corp. (Louisville, Colorado)

Storage Technology Corp. (StorageTek) offers a range of disk-array products, including the Shared Virtual Array Series for mainframe and open systems environments, the D-Series (which StorageTek sources from LSI Logic) for entry-level through enterprise open-systems markets, and the B-Series BladeStore product, which is an ATA-based array for open systems.

Sun Microsystems (Palo Alto, California)

Sun has been supplying storage for its Unix-based systems for many years. Its line of StorEdge arrays was originally launched in January 1998 and has had frequent refreshes to keep it current. Today, Sun offers the StorEdge 3300 and 3500 Series for entry-level workgroup environments, and the StorEdge 3900 Series and the StorEdge 6000 family for the midrange. Sun also has the StorEdge 9970 and 9980 for the high-end market, which it sells as part of its distributor agreement with Hitachi/HDS.

Other RAID Vendors

A number of smaller vendors also play a role in this market. They include 3PARdata (Freemont, California), BlueArc (San Jose, California), Dot Hill (Carlsbad, California), EqualLogic (Nashua, New Hampshire) and Xiotech (Eden Prairie, Minnesota).

Recommended Gartner Research

RAID Technology: Overview, DPRO-95056
NAS vs. SAN: Overview, DPRO-97417
1Q03 Update: Global Disk Storage Forecast 2002-2004, HARD-WW-DP-0433
Disk Array Storage: Comparison Columns, DPRO-90825

Insight

While storage, storage management and backup/restore capabilities have gained heightened visibility recently, data protection has always been a critical factor for businesses. Today’s disk-array storage solutions provide users with a great deal of flexibility, allowing them to easily configure a system that precisely meets their availability needs, their data protection requirements and, equally important, their budgets. The move now is toward improved software-management capabilities that will help businesses solve the problems they face in today’s 24×7×365 world.