

RAID 6 with HP Advanced Data Guarding technology: a cost-effective, fault-tolerant solution

technology brief



Abstract.....	2
Introduction.....	2
Functions and limitations of RAID schemes	3
Fault tolerance of RAID schemes	5
Cost-effectiveness of RAID schemes	7
Performance of RAID schemes	8
Choosing a RAID level	9
Summary	9
Call to action	10

Abstract

RAID 6 with HP's patented Advanced Data Guarding (ADG) technology is a cost-effective solution for storing large volumes of enterprise data with fault tolerance. Its performance, like that of other RAID levels, depends on the nature of the application.

Organizations implementing a large drive array should consider RAID 6 because it can tolerate up to two simultaneous drive failures without downtime or data loss. By differentiating among the available RAID schemes, this paper provides information to help IT managers select the RAID scheme that will best meet all the needs of their specific computing environment.

Introduction

An increasingly important IT challenge is finding cost-effective storage technologies to protect the data that businesses amass as a result of e-business and traditional applications such as transaction processing, enterprise resource planning, and decision analysis. An effective storage solution must meet three very important needs: fault tolerance, efficient use of storage capacity, and high performance. Organizations implementing a large storage array should consider an HP RAID 6 solution because it can tolerate up to two simultaneous drive failures without downtime or data loss.

This paper describes the functions and limitations of available RAID schemes for protecting data in large storage systems. It describes the most important factors for consideration in choosing a storage solution. By differentiating among the available RAID¹ schemes, this paper provides information to help IT managers select the RAID scheme that will best meet all the needs of their specific computing environment.

¹ RAID is an acronym for redundant array of independent disks.

Functions and limitations of RAID schemes

Before creating large arrays with a high number of disk drives or with high-capacity disk drives, IT managers should consider the limitations of available RAID schemes in protecting data during a single- or multiple-drive failure. RAID schemes, called levels, are differentiated by the method each uses to provide fault tolerance. Note that the RAID level numbers do not correlate with the degree of fault protection provided. Table 1 illustrates the RAID levels described in this section.

In a RAID 0 implementation, user data is striped² across all the drives in the array. For large files, reading this data in parallel from the separate drives is faster than reading the file from a single drive. Also, many small files can be read in parallel. However, this RAID scheme offers no fault tolerance; the entire array will fail if one drive fails.

RAID 1 is a mirroring scheme that stores identical data on two sets of drives. It is used in applications that require very high availability. RAID 1 has high fault tolerance, but it has low storage efficiency because it requires twice the number of drives required for RAID 0.

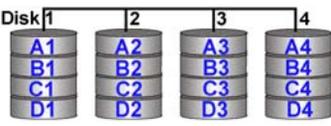
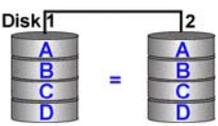
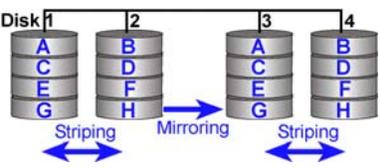
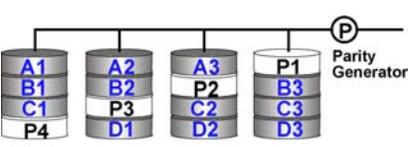
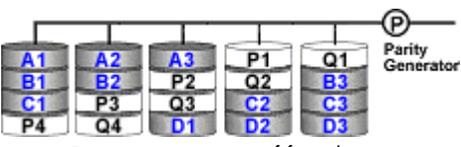
RAID 1+0 is implemented as a striped array of mirrored drives. It is best suited for sites that need high performance and maximum reliability, but are willing to forgo storage efficiency. RAID 1+0 can withstand the failure of half the drives as long as no two drives in a mirrored pair fail; however, it sacrifices storage efficiency.

RAID 5 is implemented as a striped array of three or more drives. Parity information is calculated for each stripe of data and is placed on a different drive than the related data (see Table 1). The parity information is spread across all drives in the array and occupies the equivalent capacity of one physical drive. RAID 5 provides good performance and can withstand the loss of a single drive without failure of the array. If a second drive fails before the first failed drive can be replaced, however, the entire array will fail.

RAID 6 (ADG) is an extension of RAID 5 for implementation on arrays of four or more drives. The data and two sets of parity information are striped across all drives in the array. The additional set of parity improves the fault tolerance of the array but results in lower write performance. The two sets of parity information are stored in different locations across the drives in the array and occupy the equivalent capacity of two physical drives. RAID 6 protects against the simultaneous failure of two drives in the array.

² Striping is the distribution of data over multiple disk drives to improve performance. Data is interleaved in groups of sectors known as “stripes” across the drives.

Table 1. Summary of RAID technologies for large arrays

RAID LEVELS	Function/Applications	Limitations
<p style="text-align: center;">RAID 0</p>  <p style="text-align: center;">Requires a minimum of one drive.</p>	<p>Data is distributed across separate disk drives.</p> <hr/> <p>Image Editing • Video Production • Pre-Press Applications</p>	<p>Highly vulnerable to failure. The entire array will fail if one drive fails.</p>
<p style="text-align: center;">RAID 1</p>  <p style="text-align: center;">Requires a minimum of two drives.</p>	<p>Mirroring - Identical data stored on two drives, high fault tolerance, very good performance (higher read performance than RAID 0).</p> <hr/> <p>Accounting • Payroll • Financial</p>	<p>50% of capacity dedicated to fault protection. Doubles the number of drives required.</p>
<p style="text-align: center;">RAID 1+0</p>  <p style="text-align: center;">Requires a minimum of four drives.</p>	<p>Implemented as striped, mirrored disks.</p> <hr/> <p>Database applications requiring high performance and fault tolerance; sacrifices storage efficiency.</p>	
<p style="text-align: center;">RAID 5</p>  <p style="text-align: center;">Requires a minimum of three drives. Pn represents one set of parity.</p>	<p>One set of parity data is distributed across all drives. Protects against the failure of any one drive in an array.</p> <hr/> <p>Transaction processing • File and application servers • ERP • Internet and Intranet servers</p>	<p>Potentially risky for large arrays. Can only withstand the loss of one drive without total array failure. Low write performance (improved with battery-backed cache).</p>
<p style="text-align: center;">RAID 6 (ADG)</p>  <p style="text-align: center;">Requires a minimum of four drives. Pn and Qn represent two sets of parity.</p>	<p>Two sets of parity data are distributed across all drives. Protects against the failure of two drives in an array. Provides higher fault tolerance than RAID 5.</p> <hr/> <p>For 24x7 applications that require a higher level of fault tolerance than RAID 5.</p>	<p>Lower write performance than other RAID levels. Sequential and burst-write performance can be much improved with battery-backed cache.</p>

Fault tolerance of RAID schemes

Often, the terms *reliability* and *fault tolerance* are used interchangeably in describing RAID schemes; however, there is a distinction between them. Reliability refers to the likelihood that an individual drive or drive array will continue to function without experiencing a failure. Reliability is typically measured over some period of time.

Fault tolerance, on the other hand, is the ability of an array to withstand and recover from a drive failure. Fault tolerance is provided by some sort of redundancy—mirroring, parity, or a combination of both—and it is typically measured by the number of drives that can fail without causing the entire array to fail. The fault tolerance of various RAID levels is as follows:

- RAID 0 has no fault tolerance because it provides no type of redundancy. The array will fail if one physical drive fails.
- With RAID 1 or RAID 1+0, up to $n/2$ hard drives can fail without causing array failure—assuming that none of the failed drives are mirrored to each other. In practice, logical drive failure is more likely to occur before $n/2$ drives fail. The array will fail if a drive and its mirror both fail; however, the probability of this decreases as the number of mirrored pairs increases.
- RAID 5 can withstand the failure of only one physical drive. If a second drive should fail before the first failed drive is replaced, the array will fail. Therefore, HP recommends the use of an online spare drive in RAID 5 configurations. With an online spare drive in the array, when a drive fails, a rebuild of the data on the failed drive begins immediately. Therefore, the array will fail only if a second drive should fail during the brief process of rebuilding the data onto the spare drive.
- RAID 6 can withstand the failure of two physical drives. Three hard drives must fail before the entire array will fail. RAID 6 also protects against the loss of data if a drive fails and a defect occurs in a single sector of another drive. This is important if data is being rebuilt after a drive failure and a media defect occurs in one of the good drives.

Although RAID 1 and RAID 1+0 provide a higher level of fault tolerance than RAID 5, that protection comes at a very high price, because 50 percent of the drives are dedicated to fault protection. For RAID 5 configurations, HP recommends using no more than 14 physical drives per array due to the increased likelihood of drive array failure with more hard drives.

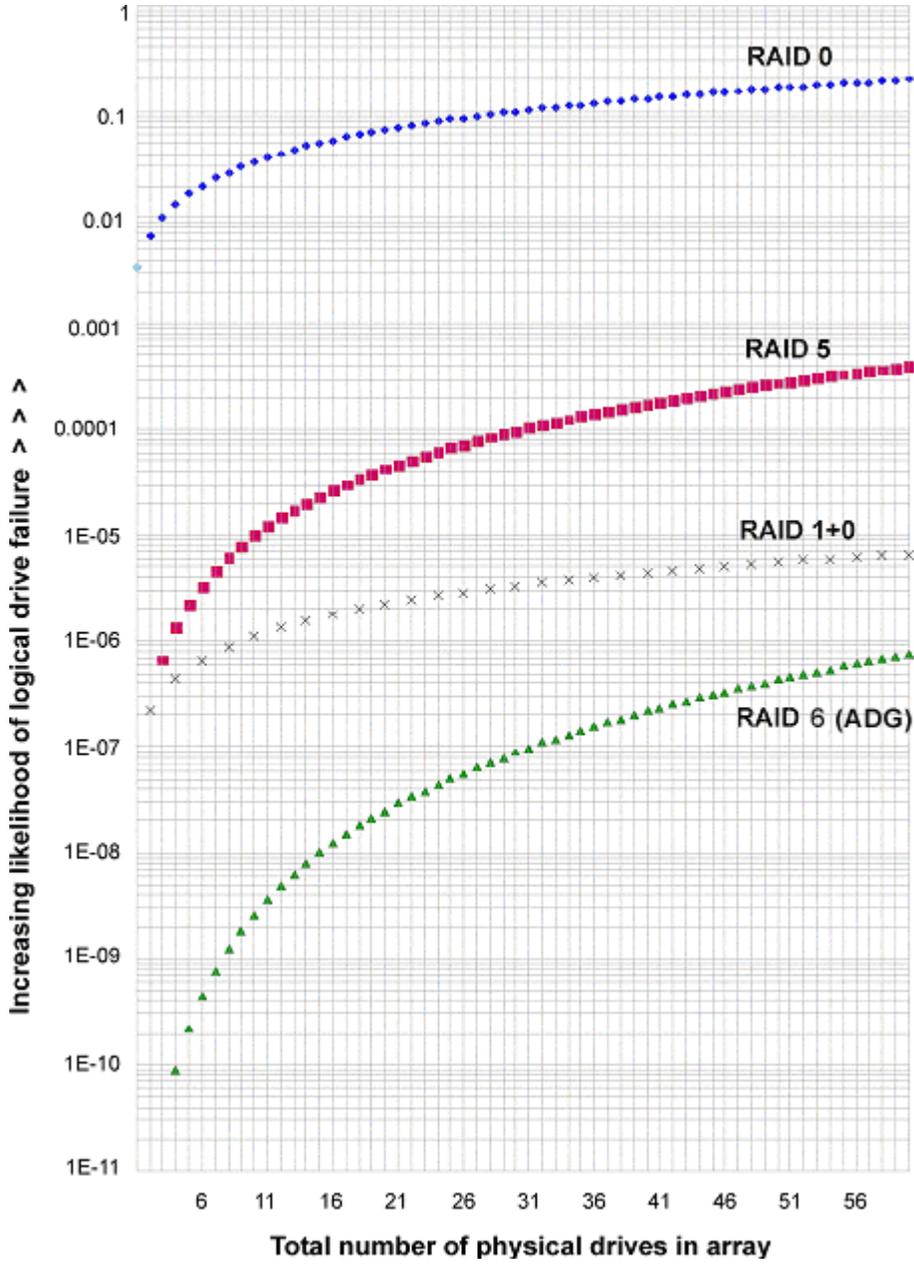
For arrays of more than 14 drives, HP recommends RAID 6 for its fault tolerance and storage efficiency. RAID 6 can effectively protect an array containing the maximum number of drives supported by a variety of Smart Array Controllers. Controller specifications are available online from this web page: www.hp.com/products/smartarray.

Figure 1 shows the relative probability of logical drive failure for different RAID levels and different logical drive sizes, assuming the array contains no online spares. A logical drive failure is less likely with RAID 6 than with RAID 0, RAID 5, and RAID 1+0.

An online spare (hot spare) can be added to any of the fault-tolerant RAID levels to reduce the probability of logical drive failure: As soon as a drive fails, missing data can be automatically rebuilt onto the online spare from parity data. Without an online spare, there is a greater chance of array failure and consequent loss of data, if a subsequent drive failure occurs before the failed drive can be replaced. Data loss is less likely with RAID 6 than with RAID 5 because RAID 6 can sustain failure of two drives. RAID 6 supports online spare drives and Online RAID Level Migration from any other RAID level.³

³ For more information about online spare drives and Online RAID Level Migration from RAID 1 or RAID 5, refer to the HP Smart Array 6400 Series Controller Support Guide, <http://docs.hp.com/en/J6369-90011/index.html>

Figure 1. Failure probability for logical drives with four RAID levels and varying numbers of drives in the array



Cost-effectiveness of RAID schemes

The cost effectiveness of each RAID solution is a balance between the total cost of the array and its usable capacity. While the total cost includes all the drives in the array, the usable capacity includes only the drives that store non-redundant (not parity or mirrored) data. One way to evaluate cost effectiveness is to compare the cost per gigabyte of usable capacity of various RAID levels. Another useful way to evaluate cost effectiveness is to compare storage efficiency—the usable capacity divided by the total of capacity of all the drives.

Note:

RAID 6 is supported on a variety of Smart Array Controllers. The complete list of controllers and support requirements is available online at this URL: www.hp.com/products/smartarray.

An important factor to note is that the usable capacity of any RAID array is limited by the size of the smallest hard drive in the array; the extra capacity on larger drives goes unused. For example, an array with four drives (40 GB, 60 GB, 60 GB, and 60 GB) would have a usable capacity of 4 x 40 GB, or 160 GB. To maximize storage efficiency, all RAID array drives should have the same capacity. If drives with different capacities are attached to the same controller, it is possible to create multiple arrays that contain only drives of the same capacity.

Table 2 lists the storage efficiencies of the various RAID levels. The storage efficiency of RAID 1 and RAID 1+0 is constant, but the storage efficiency of RAID 5 and RAID 6 varies with the number of drives. The number of parity drives in RAID 5 and RAID 6 schemes is fixed (one parity drive for RAID 5 and two parity drives for RAID 6), so their storage efficiency increases with the number of drives.

As shown in Table 2, RAID 1 and RAID 1+0 have the lowest storage efficiency at 50 percent; therefore, they are less cost-effective solutions for large arrays. RAID 5 and RAID 6 have much higher storage efficiencies, but the level of efficiency depends on the number of drives in the array. For a given number of drives, RAID 5 will have higher storage efficiency than RAID 6; but this difference shrinks as the number of drives increases. The storage efficiency of a RAID 5 array varies from 67 percent for three drives to 93 percent for 14 drives (the maximum recommended by HP). The storage efficiency of RAID 6 varies from 50 percent for four drives to 96 percent for specific storage systems. The maximum number of physical drives that each HP Smart Array controller can support is identified on this web page: www.hp.com/products/smartarray

Table 2. Summary of RAID array storage efficiency*

	RAID 1	RAID 1+0	RAID 5	RAID 6 (ADG)
Usable Capacity (C = capacity of smallest drive; n = number of drives)	$C*(n/2)$	$C*(n/2)$	$C*(n-1)$	$C*(n-2)$
Minimum number of drives	2	4	3	4
Recommended maximum number of drives*	N/A	N/A	14	N/A
Storage efficiency from minimum to recommended maximum number of drives**	50%	50%	67% to 93%	50% to 96%

*HP recommends not exceeding these maximum figures (excluding any allowable online spares) when configuring a drive array, due to the increased likelihood of drive array failure if more hard drives are added.

**The value for storage efficiency is calculated by assuming all drives in the array have the same capacity and that there are no online spares in the array.

Performance of RAID schemes

The key to RAID performance is parallelism—the ability to access multiple disks simultaneously. Parallelism allows data to be written to or read from a RAID array faster than would be possible with a single drive. Analyzing RAID performance can be very complicated because several factors must be considered (sequential versus random reads and writes, block size, data transfer rate, etc).

The performance of a RAID array can be subdivided into read performance and write performance; both will vary based on the RAID level.

- RAID 0 uses striping to improve performance by distributing user data across multiple hard disks; however, RAID 0 has no fault tolerance.
- RAID 1 (mirroring) writes the data and redundant data to two separate drives. The data is normally read from one drive, so the read performance is much faster than the write performance; however, half of the data can be read from each drive to further increase the read performance.
- RAID 5 and RAID 6 also use striping, but their write performance is significantly affected by the multiple reads and writes needed to perform the parity calculations prior to updating the array. The write performance of RAID 6 is less than that of RAID 5 because RAID 6 has dual parity overhead. The read performance of RAID 5 and RAID 6 is very good and may be improved by adjusting the stripe size.

In the final analysis, RAID array performance boundaries are largely predetermined by the intended application. Applications such as ERP, transaction processing, and web servers—which require a high-capacity array but have a relatively low ratio of writes to reads—may benefit from striping with parity: RAID 5 or RAID 6. On the other hand, file servers, database servers, and media development servers—applications that have a much higher ratio of writes to reads—may benefit from a RAID 1+0 array. However, with RAID 1+0 arrays, cost eventually becomes an issue as capacity requirements grow.

Choosing a RAID level

To choose the optimum RAID level for data protection in large arrays, IT managers should consider a variety of factors, including:

- Fault tolerance (based on availability requirements)
- Cost effectiveness (based on storage efficiency or cost per gigabyte of usable capacity)
- Performance

The decision chart in Table 3 is an aid for determining which RAID level will provide the best solution for a specific computing environment. For example, if cost effectiveness is of primary importance and fault tolerance is of secondary importance, or vice versa, the best choice is RAID 6.

Table 3: Decision chart for choosing the optimum RAID level for large arrays

Most important	Secondary importance	RAID level choice
Cost effectiveness	Fault tolerance →	RAID 6 (ADG)
	Performance →	RAID 5 (RAID 0 if fault tolerance is not needed)
Fault tolerance	Cost effectiveness →	RAID 6 (ADG)
	Performance →	RAID 1+0
Performance	Cost Effectiveness →	RAID 5 (RAID 0 if fault tolerance is not needed)
	Fault tolerance →	RAID 1+0

Summary

RAID 6 with HP's patented Advanced Data Guarding technology provides an advanced level of data protection for computing environments requiring a higher level of fault tolerance than RAID 5 and a lower implementation cost than RAID 1. RAID 6 is best implemented when IT organizations need to protect enterprise data at a lower cost than RAID 1 arrays and when performance is not an overriding factor.

RAID 6 can effectively protect an array of up to the maximum number of drives supported by a variety of Smart Array Controllers. A RAID 6 array can tolerate up to two simultaneous drive failures without downtime or data loss. RAID 6 supports Online Spare Drives and Online RAID Level Migration from any RAID level.

Call to action

To help us better understand and meet your needs for ISS technology information, please send comments about this paper to: TechCom@HP.com.

© 2002, 2005 Hewlett-Packard Development Company, L.P. The information contained herein is subject to change without notice. The only warranties for HP products and services are set forth in the express warranty statements accompanying such products and services. Nothing herein should be construed as constituting an additional warranty. HP shall not be liable for technical or editorial errors or omissions contained herein.

TC050604TB, 06/2005

