RAID Configuration: Pragmatic Selection Strategies

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Introduction

Choosing the right configuration for the logical disks of your systems is no trivial task. But it is still one, many technicians are faced with.

The aim of this report is to offer practical approaches for selecting the appropriate configuration for a specific task, without delving into the underlying technical intricacies. It adopts a narrow perspective, focusing solely on factors such as reliability, capacity, cost, and performance, while disregarding considerations like access protocols or optimized implementations. Nevertheless, the provided information can serve as a foundation for calculating and comparing theoretical values, empowering readers to make more informed decisions or conduct additional research.

The methodology employed in this report is primarily based on the analysis of readily available information online. Due to the non-scientific nature of this approach, most of the information was not verified beyond basic plausibility checks. It's important to note that no quantifiable empirical measurements were conducted as part of this study.

The report is structured into five main parts. The first four sections provide essential information on comparing reliability, capacity, cost, and performance. In the final section guide, a straightforward overarching method is presented, along with additional vendor-specific information contained within this chapter.

Contents

1 Reliability

Due to the complexity of real-life situations, simple numeric methods may not provide conclusive results. For instance, when considering the average failure time of a single drive and then extrapolating it across a storage group, the probability of a drive failing will evidently increase significantly with a higher number of drives. Analytically defining this change is challenging due to its dependency on various factors. For example, it's frequently observed that drives from the same production batch may fail together in short succession, making it difficult to determine such factors definitively. [1]

Still, if one wants to get a simple overview, formulas are included for the failure calculation for RAID-5 and RAID-6.

$$\frac{MTTF^2(disk)}{N * (G-1) * MTTR(disk)} \tag{1}$$

Equation 1 gives a way to calculate the mean time to failure of RAID-5 arrays. Where $MTTF(disk)$ is the mean time of failure of a single disk N is the number of disks and G is the size of the arrays. The equation assumes no correlated failures, that means that this simple model assume all disks are independent. The same calculation looks slightly different for RAID-6 as seen in eqation 2. [1]

$$\frac{MTTF^3(disk)}{N * (G-1) * (G-2) * MTTR^2(disk)} \tag{2}$$

An overview of the hardware failures that can occur without disrupting service is presented in Table 1. It's worth noting that in RAID-1, the impact of a failure largely depends on luck regarding the location of the failure. If the stripes are favorably replicated, multiple drives may be able to fail without service disruption. [2]

Level	Failures
0	0
1	1 or $\frac{n}{2}$
2	1
3	1
4	1
5	1
6	2

Table 1: Amount of drives able to fail without array service degradation [2]

2 Capacity

A comparative capacity calculation can relatively easily be done using table 2.

Level	Space Efficiency
0	n
1	$\frac{n}{2}$
2	$(1 - \frac{1}{n} * log_2(n+1)) * full_caption$
3	n-1
4	n-1
5	n-1
6	n-2

Table 2: Coefficient of the space multiplication (smallest disk). [2] The calculation of RAID-2 was derived from Chen et al., Alagappan and wikipedia. [1][2]

3 Cost

An economic comparison can be facilitated using the matrix illustrated in Table 3. It's practical to assess the cost relative to RAID level-0, as it represents the configuration with the lowest cost/efficiency rating. To compare the various options, utilize $N =$ Number of disks and $\max(x, y)$ as the known max function with $x, y \in R$. In this calculation, "small" denotes I/O requests of one striping unit, while "large" denotes I/O requests of one full stripe (one stripe unit from each disk in an error-correction group). The overview can be seen in figure 3 which plots this against arrays of different sizes. [1]

Level	Small Read	Small Write	Large Read	Large Write	Storage Efficiency
0	1	1	1	1	1
1	1	$\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{2}$
3	$\frac{1}{N}$	$\frac{1}{N}$	$\frac{N-1}{N}$	$\frac{N-1}{N}$	$\frac{N-1}{N}$
5	1	$\max\left(\frac{1}{N}, \frac{1}{4}\right)$	1	$\frac{N-1}{N}$	$\frac{N-1}{N}$
6	1	$\max\left(\frac{1}{N}, \frac{1}{6}\right)$	1	$\frac{N-2}{N}$	$\frac{N-2}{N}$

Table 3: Cost Throughput Comparison relative to RAID-0 [1]

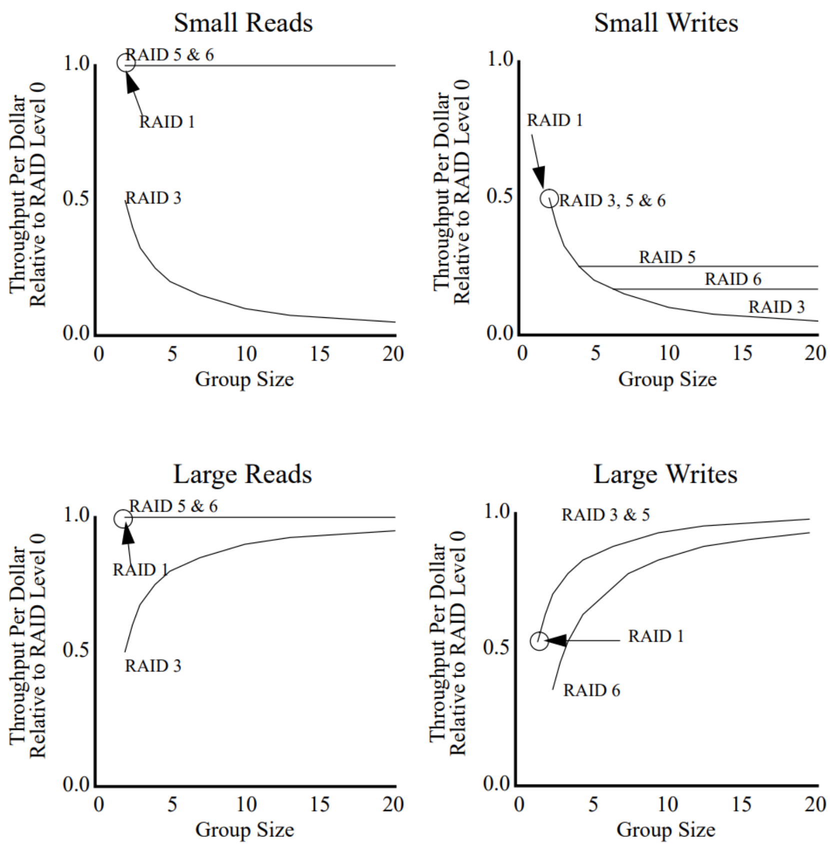

Figure 1: Cost Throughput Comparison

4 Performance

You can approximate the theoretical upper bound of performance using Table 4. The calculation considers only conceptual first-order factors. Despite this limitation, comparing these fundamental boundaries can still be beneficial for outlining performance expectations. The table provides coefficients that can be multiplied by the given drive metrics (random read, random write, sequential read, sequential write). It's important to note that this approach does not specify block sizes and can be applied to average or median values. [2]

4.1 Nested RAID Configuraitions

For nested RAID configurations, begin by calculating the values for a single group, and then iterate the calculation. Distribute the group size evenly across the total number of disks.

For instance, calculate the table for a single RAID-5 group first, and then take those values and plug them back into the table again. It's important to note that this approach does not include many optimizations typically implemented on platforms. Again keep in mind, that this is only an approximation. Also

Level	sread	swrite	rread	rwrite	rlatency	wlatency
0	n	n	n	n	1	1
1	$\frac{n}{2}$	$\frac{n}{2}$	n	$\frac{n}{2}$	1	1
4	n-1	n-1	n-1	$\frac{1}{2}$	1	2
5	n-1	n-1	n	$\frac{n}{4}$	1	2
6	n-2 [1]	n-2 [1]	n [1]	$\frac{n}{6}$ [1]	1 [1]	2 [1]

Table 4: Performance Calculation [2], The original talbe does not include RAID-6 so it was derived from Chen et al [1]

notice, that with increasing number of disks the upper bound of the throughput can be amplified, but generaly latency is not improved.

4.2 Other Factors

It's crucial to always refer to specific hardware and software documentation, as theoretical speeds heavily rely on particular implementations. Factors such as controller features, choice of algorithms, and caching mechanisms play an immense role in determining actual performance. In the most general case, we assume that these factors scale with a constant value.

Additionally, it's important to consider other variables that can impact performance, such as network latency, system workload, and environmental conditions. By thoroughly understanding the specific characteristics of the hardware and software being used, one can better optimize configurations and make more accurate performance assessments. Furthermore, staying informed about updates and advancements in technology can help ensure that systems are operating at their highest potential.

5 Guide

For a fast comparison use the Microsoft Excel workbook "raid-workbook.xlsx" supplied with this report. Plug in the dependant variables like drive size and io speeds and further analyze the results.

5.1 HPE Smart Array

HP offers different storage solutions, one of these consists of the Smart Array Controllers, which offer different functionalities separated by classes. In this chapter an overview is given and it is presented, what HP writes about the topics reliability, performance and efficiency.

There are three main classes: S,E and P. S-Class provides a typical software RAID solution for MS Windows environments and is an entry level product. Next in line is the E-Class physical controllers which offer enterprise level functionalities but not all high performace optimiziations like caching. Last in line are P-Class physical controllers which offer typical performance oriented functionalities and optimizations like chaching and different types of interfaces. For the exact feature matrix consult the documentation found online. [3]

Performance whise HP suggests to consider, that the performance decreases as fault tolerance improves due to extra I/O as well as that read performance is generally the same for all RAID levels except for smaller RAID 5 or 6 arrays. [3]

In their documentations they almost show the same theoretical numbers to create a performance comparison. They simplify their model on the basis of needed write io operations.

- RAID-0, 1x Steps IO
- RAID-1/10, 2x Steps IO
- RAID-1/10 Triple, 3x Steps IO
- RAID-5, 4x Steps IO
- RAID-6, 6x Steps IO

This has evidently a big enough similiarity to the model used in chapter "Performance".

For the capacity aspects, they suggest to consider, that usable capacity decreases as fault tolerance improves due to an increase in parity data. Further they say, that the usable capacity for RAID 10 and RAID 10 Triple remains flat with larger arrays and that the usable capacity for RAID 5, 50, 6, and 60 increases with larger arrays. [3]

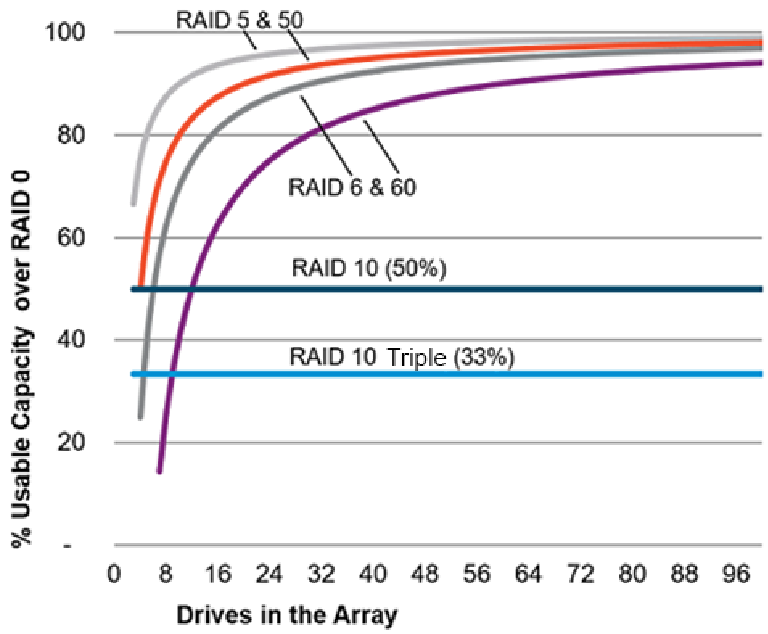

Figure 2: HP Storage Efficiency [3]

Figure 5.1 shows a general plot of the storage efficiency development over a increasing amount of disks. The plot assumes the group size 2 for RAID-50 and RAID-60. [3]

At last consider following suggestions by HP:

- RAID 1/10 Triple: Optimize for fault tolerance and write performance.
- RAID 6/60: Optimize for fault tolerance and usable capacity.
- RAID 1/10: Optimize for write performance.
- RAID 5/50: Optimize for usable capacity.

Fun Facts

It seems that RAID initially stood for "Redundant Array of Inexpensive Disks" before evolving into the more widely recognized version, "Redundant Array of Independent Disks." Source is: trust me brother; cannot be bothered to look it up.

List of Figures

List of Tables

References

[1] P. Chen, E. Lee, G. Gibson, R. Katz, and D. Patterson, "Raid: High-performance, reliable secondary storage," tech. rep., Carniege Mellon University, n.d.

[2] R. Alagappan, "Cs 537: Raid," tech. rep., University of Wisconsin, 2019.

[3] HPE, "Hpe smart array sr gen10 controller user guide," tech. rep., HP, 2024.

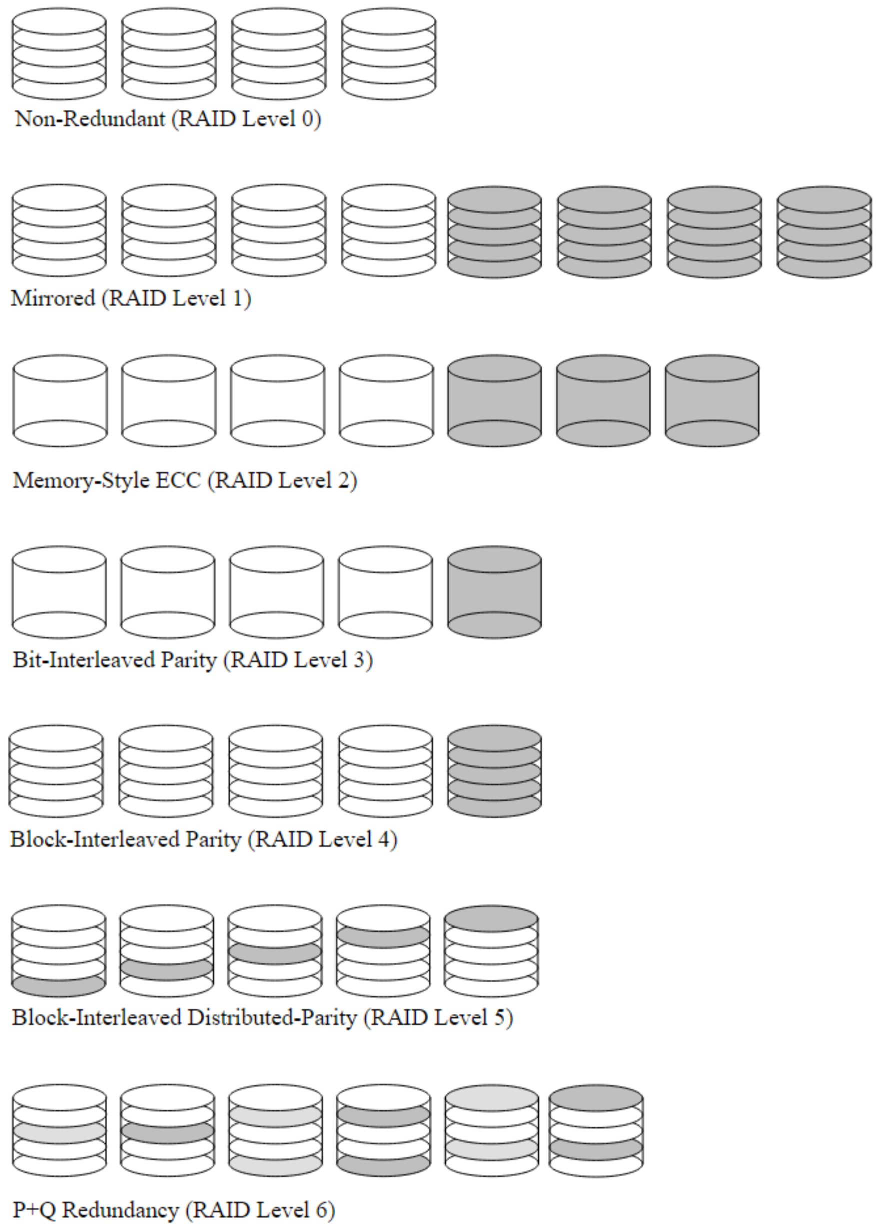

Figure 3: Raid Overview [1]