Apacer

Over-provisioning

White Paper

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1. Introduction

In recent years, the development of 3D NAND TLC technology has meant that large-capacity flash drives are surprisingly affordable. In the past it was common to measure drive size in megabytes, but now gigabytes are more common, and even terabyte drives are common in the commercial market. Having sufficient capacity to store large amounts of data is therefore more affordable than it ever has been.

With this in mind, Apacer developed the over-provisioning method. This requires users to devote a small amount of capacity, but delivers significant improvements in both endurance and sustained write performance. By distributing the total number of writes and erases across a larger population of NAND flash blocks and pages over time, over-provisioning can enhance the efficiency of the Garbage Collection process, which has the effect of increasing endurance. And by giving the flash controller additional buffer space for managing program/erase cycles, it can improve performance, by increasing the probability that a write operation will have immediate access to a pre-erased block.

This white paper will investigate and explain how over-provisioning is accomplished and the proven benefits of this technology.

2. How Over-provisioning Works

In the past, when an SSD was shipped to a buyer, almost the entire capacity was available as user capacity. A small amount – typically around 6.8 percent – was set aside for crucial operations such as building a mapping table, and was referred to as the “system reserved” portion.

However, manufacturers quickly discovered that SSDs were susceptible to write amplification when compared to traditional HDDs. Write amplification is an undesirable phenomenon that affects SSDs wherein the amount of data actually written to a drive is a multiplication of the amount that the user is trying to write. This occurs because flash memory must be erased before it can be overwritten, and therefore the process for writing any particular piece of data may involve moving (or rewriting) user data or metadata more than once. Since every write and erase operation uses up a tiny portion of the drive’s operational lifespan, write amplification indicators mean that the lifespan of an SSD will be shortened.

Let’s examine an example. In an ideal world, the write amplification indicator would be as low as possible, i.e. 1. But in a standard flash drive with a total capacity of 128GB, and a data cache of 128KB, a write amplification indicator of 1.68 is more likely, based on real-world tests.

Apacer’s engineers developed an over-provisioning algorithm to combat this issue. To continue with the example, they would apply over-provisioning to a standard flash drive with a total capacity of 128GB and a data cache of 128KB. However, 7 percent of the flash drive’s capacity would be set aside for over-provisioning. When this amount is removed from the user capacity (along with the System Reserved portion), the remaining user capacity would be 120GB.

However, thanks to the over-provisioning technology, the write amplification indicator would be reduced from 1.68 to 1.47 – a reduction of 14%. This would significantly extend the operational

lifetime of the drive, compared to a drive with the same specs that did not incorporate over-provisioning. In fact, if the entire volume of the 128GB drive was written once a day, tests show that the drive with over-provisioning would last 5.59 years, while the drive without it would last just 4.89 years.

If the drive size was increased, the benefits of over-provisioning would become even more apparent. A 256GB flash drive with a data cache of 128KB, but without over-provisioning, has been measured to have a write amplification indicator of 1.70. A drive with the same specs that gives 7 percent of its capacity over to over-provisioning would have a user capacity of 240GB. However, the write amplification indicator would be reduced from 1.70 to 1.36 – an improvement of 25 percent. If the entire volume of the 256GB drive was written once a day, the drive with over-provisioning would last 6.04 years, while the drive without it would last just 4.62 years.

3. The Advantages of Over-provisioning

As was previously explained, over-provisioning offers real benefits to the user when it comes to extending drive endurance and, by extension, operational lifetime. But there are other advantages to over-provisioning that users can enjoy. They will be discussed in this section.

Apacer's in-house engineering team carried out extensive tests on SSDs that had been equipped with over-provisioning, and compared them directly to SSDs with identical specifications that had not be equipped with over-provisioning. The results of these tests allowed them to better quantify the advantages of over-provisioning and illustrated how valuable this technology can be to industrial manufacturers in particular. Similar tests carried out by various third parties have subsequently confirmed these advantages.

One area in which performance is markedly improved is in background processes, such as garbage collection. Figure 1-1 displays the results of a test carried out on drives without over-provisioning.

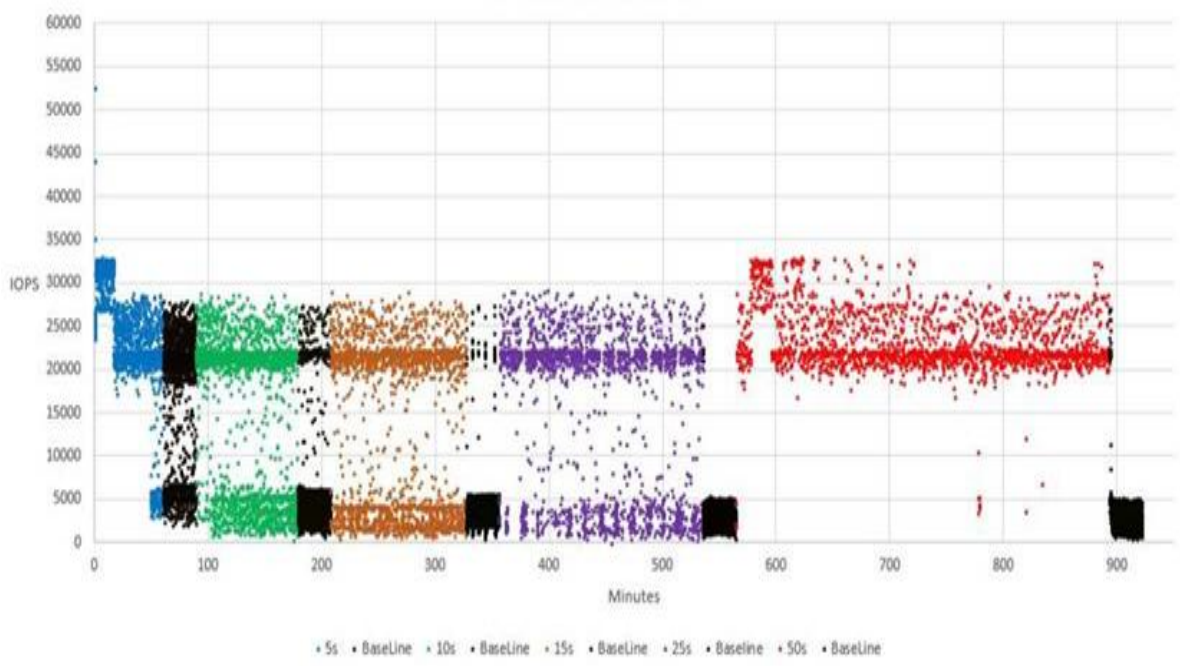

Figure 1-1 Background Processing Performance – Drive Without Over-provisioning

The test reveals a variety of different speeds for garbage collection, as measured in IOPS. The lowest speed recorded is around 17,000 IOPS, and the highest speed recorded is around 33,000 IOPS. There are a variety of different speeds that fall within this range, but it's quite a wide range, from the slowest speed to the highest speed.

Figure 1-2, on the other hand, shows the performance of an identical SSD that is equipped with over-provisioning.

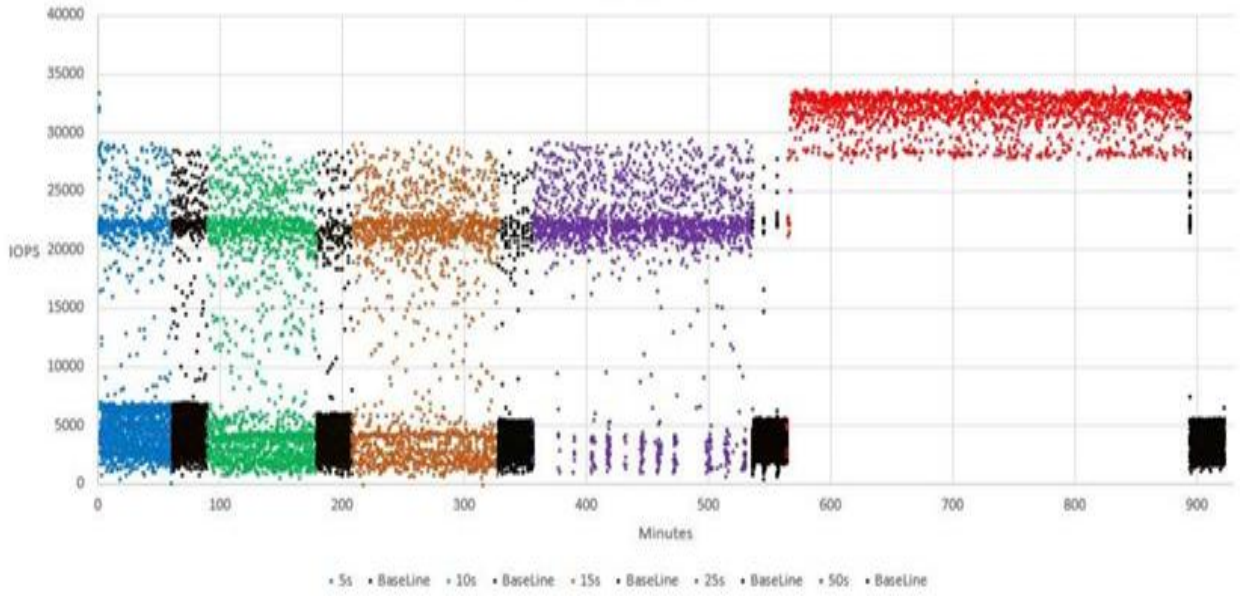

Figure 1-2 Background Processing Performance – Drive With Over-provisioning

Similarly to the first test shown in Figure 1-1, the second test also records an upper limit for background processing at around 33,000 IOPS. But the key difference is that the lowest speed recorded for background processing in Figure 1-2 is 28,000 IOPS. In other words, the first test shows a wide range of background processing speeds, while the second test shows a narrower range, with background processing speeds consistently delivering superior performance even when they dip to their lowest speeds. It's the over-provisioning technology that allows the second test to deliver these impressive results.

Over-provisioning technology also improves drive performance when it comes to 4K sustained write speeds, as demonstrated in Figure 1-3.

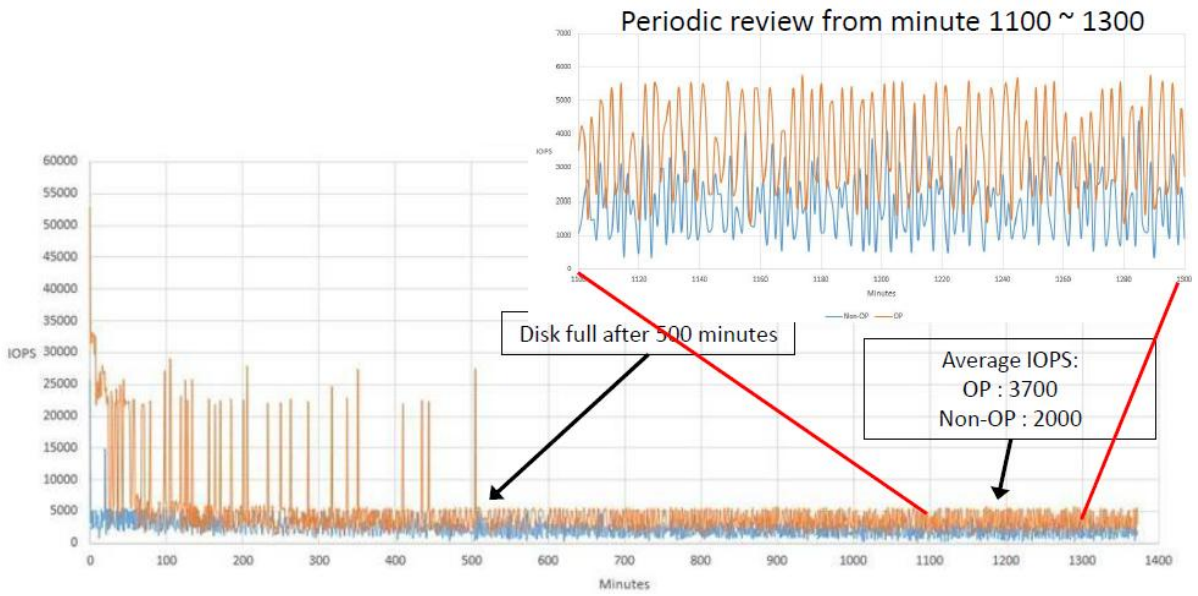

Figure 1-3 4K Sustained Performance on Drives With and Without Over-provisioning

As the data shows, the 4K sustained performance of a drive equipped with over-provisioning technology is consistently higher than one which is not. On average, in fact, the 4K sustained performance of the drive with over-provisioning is 85% higher.

4. Conclusion

Although some users are still resistant to accept over-provisioning due to the sacrifice of total capacity that it requires, a deep investigation of over-provisioning clearly demonstrates that the advantages clearly outweigh the drawbacks. The improvements in endurance and performance are more than worth the amount of capacity that is required. In fact, although 7% is the standard amount of capacity that is usually set aside for over-provisioning, 14% or larger capacity over-provisioning will offer even better rewards on investment. Apacer is willing to adjust over-provisioning capacities upon special request. Any industrial manufacturers who demand the highest levels of performance and longevity owe it to themselves to seriously consider adopting Apacer SSDs with over-provisioning technology.

Revision History

Revision	Description	Date
1.0	Official release	9/19/2019

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