The Value of Enterprise SSHD

Technology Paper

Part 1. Enterprise SSHD Basics

The purpose of this paper is to consider the value of a solid state hybrid drive (SSHD) for enterprise applications. An SSHD is a hybrid storage device that combines a traditional magnetic disk drive and complementary solid state storage to achieve a blend of high capacity and high performance for *hot* (frequently read) data.

An enterprise SSHD that improves *real* workloads by up to 3× over a traditional hard drive (HDD) at only a modest price premium creates a favorable value proposition in today's storage marketplace. Enterprise SSHDs can even find a performance edge among the increasingly adopted 15K-RPM performance HDDs, offering improved combinations of speed and capacity needed for demanding enterprise storage and server applications.

Opportunity for Improved Performance

In the past, hard drive performance has been improved by increasing RPM. However, increasing RPM is not as simple as putting in a faster motor. The impact of this strategy on the recording and servo systems of HDDs have been among the most difficult drive design challenges faced over time.

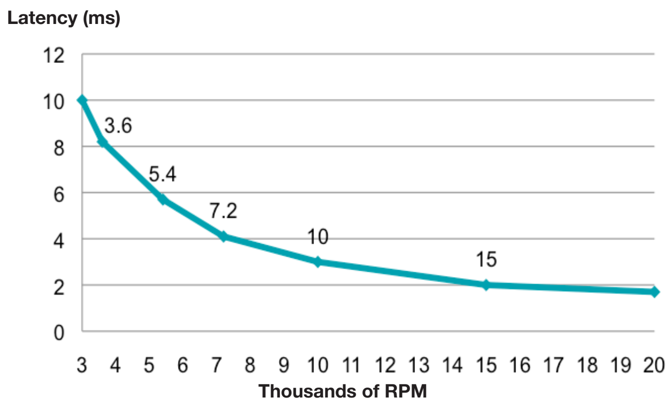

Figure 1. Latency as a function of RPM

Figure 1 shows the fundamental limitation of this approach. Moving forward, an enormous increase in RPM—perhaps up to 25K or 30K RPM—would be needed to realize the improved latency levels achieved with earlier advancements. This creates two primary barriers for enterprise applications:

1. Increasing areal density—already a challenge for hard drive manufacturers—becomes even more difficult at higher RPM.
2. Power consumption is increased, pushing hard drives in the opposite direction from where the industry wants to go in reducing power usage in data centers.

With these obstacles in mind, it is more advantageous to add a solid state memory complement to traditional magnetic storage devices. By doing so, these SSHDs help enterprise environments reduce latency, produce faster overall performance and prevent sacrifices to capacity.

Enterprise SSHD Components and Operation

An enterprise SSHD has three primary memory spaces. These spaces—the magnetic media, the DRAM buffer and the solid state (NAND) cache–work together to optimize performance. Below are the details of a representative hybrid, SSHD configuration.

Magnetic media

All data is stored on the disk drive media as the primary copy. If an error occurs in any of the other two media, the magnetic copy will return the correct data.

DRAM buffer

The DRAM buffer is the traffic cop for all operations. All reads go out onto the interface, having been staged into DRAM first. All writes arrive over the interface, landing in a DRAM location before moving on to magnetic media. Writes collect in the nonvolatile cache (NVC) protected selection of DRAM and are queued for writing to the magnetic media. At that time, the writes are coalesced and reordered to minimize the time needed to complete the transfers. The result is often less than a third of the time writes would take in a base drive.

NAND cache

The NAND cache is the unique element of flash memory that makes the drive an SSHD, and it serves two purposes. First, it is used to cache hot data. Since its size is far larger than DRAM, it can hold enough read data to significantly improve read performance over a corresponding base drive. For writing, the NAND cache is used to write the NVC protected area of DRAM should a power loss occur.

NVC

The nonvolatile cache (NVC) is part of the NAND component reserved to offer additional levels of data integrity protection in case of power loss instances. It is termed *nonvolatile* cache because when the system loses power, the data remains intact and can be immediately written to the magnetic media. The NVC was not previously available on base hard drives.

Drive reading

A read command causes data to be read from the magnetic media and put into the DRAM buffer before sending it out over the interface. Subsequent reads of the same data are serviced from DRAM. The drive continually monitors activity on DRAM data, and when it sees frequent accesses, that data is moved to the NAND cache, freeing up DRAM buffer space for more read data while making much more hot data available for access at solid state speeds. When hot data is requested, the drive services it from the NAND cache space.

Drive writing

Write data arriving over the interface is staged into the DRAM buffer. Periodically, the drive unites multiple writes and migrates them to the magnetic media. If power is suddenly lost, the drive uses the energy from the back EMF of the spindle motor to power the electronics long enough to copy outstanding writes from the NVC protected portion of DRAM to the NAND cache. When power is restored, the drive completes the outstanding operations saved in the NAND cache by writing the data to the magnetic media. Thus, the SSHD enjoys the performance of staging writes to the DRAM buffer without exposure to lost data that usually accompanies the write cache. Note also that the write process induces essentially no wear on the NAND cache because unexpected power failures are extremely uncommon events. (Orderly shutdown of a system results in all write data being directly written to the magnetic media, without ever touching the NAND cache.) The drive can sustain the heaviest of write workloads without any effect to the endurance of the NAND.

Benefits of SSHD operation

Several benefits accrue from this architecture. First, there is the obvious performance benefit from the large read cache and write-back caching. Less obvious is the fact that high write activity does nothing to wear on the endurance of the NAND. Since data is only written to the NAND cache when the drive wishes to stage read data and infrequently protect write data during an unexpected power loss, NAND endurance is not stressed by the SSHD function.

Even more interesting is the fact that since endurance is a function of write activity, temperature and data retention, the NAND cache in an SSHD can sustain many times the write activity of that in an SSD. This is due to the fact that an SSD must retain data for the life of the product, perhaps three to five years, while an SSHD has the magnetic media behind it to hold the data. Data in the NAND cache need only be kept for a limited amount of time so that refreshing it does not occur often enough to affect performance. In other words, if the SSHD can hold data for perhaps a day, refreshing it once in that time period will have no impact on the drive performance. This enables the NAND cache to sustain many times the writes of a device in which the NAND must retain the data for several years.

Conclusion

Reliable and expedient access to data files is critical for data centers and other enterprise environments. Yet it is the balance of high performance and high capacity that contributes to a successful storage solution for a variety of enterprise applications. An enterprise SSHD provides this valuable blend of speed and storage space to meet the needs of organizations and data centers.

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