Flash-optimized Data Progression

A Dell white paper

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Table of contents

Executive summary .................................................................................................................... 3
What is different about Dell Compellent Data Progression? ................................................. 4
SSDs — how they differ ............................................................................................................. 4
Features and benefits of Flash-optimized Data Progression .................................................. 6
Automate tasks with storage profiles for flash-optimized solutions ...................................... 7
Summary .................................................................................................................................. 9
Additional information ........................................................................................................... 10

Tables

Table 1   Enterprise-grade SAS SSD classifications ................................................................. 5

Figures

Figure 1   Tiering data with Compellent Data Progression ...................................................... 7
Figure 2   Flash Optimized Storage Profile ............................................................................. 8

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Executive summary

As the exponential data growth and the ever increasing requirement for high I/O performance with low latency continues, flash storage delivers impressive results by providing greater I/O performance and eliminating rotational and seek latencies commonly found in HDD-based storage systems. Up to now, the cost of flash storage has kept it primarily relegated for use in improving performance of the highest priority workloads. Dell™ Compellent™ unified block and file, highly scalable storage changes the economics of flash storage and opens up the use of flash to a broader set of deployments — such as OLTP systems, data warehousing systems, VDI deployments, and even less critical data sets — at a more accessible price point.

Compellent Flash-optimized solutions, which include all-flash and hybrid-flash arrays, are made possible by the introduction of higher capacity, lower cost read-intensive MLC SSDs. These SSDs combined with Data Progression enhancements can now tier data across high-endurance, high-performance, write-intensive SLC SSDs and read-intensive MLC SSDs, disrupting the current flash cost model. These tiering innovations enable a dramatic reduction of $/GB and effectively deliver flash performance at the price of a traditional rotating disk.¹

For several years, Dell Compellent Storage Center arrays have leveraged a unique application of RAID and tiering methods — Dell Compellent Data Progression — to optimize storage performance and capacity. With the emergence of higher performing controllers, as well as the rapid adoption of SSDs, Dell has a new level of Data Progression optimized for flash drives. The combination of write- and read-intensive SSDs and Flash-optimized Data Progression enables Storage Center arrays to deliver large amounts of high-performance solid-state storage at a fraction of the cost compared to other storage solutions.

To introduce Flash-optimized Data Progression, this white paper summarizes Dell’s current Data Progression techniques, gives a high-level description of SSDs, and describes the implementation of Flash-optimized Data Progression.

¹The Dell Compellent all-flash solution costs less than a comparable 15K disk drive solution based on internal Dell analysis in July 2013 using Dell Compellent flash-optimized and spinning disk US list pricing.
What is different about Dell Compellent Data Progression?

Dell Compellent Data Progression is fully automated and integrated into the storage layer. The tiering software virtualizes and moves data based on policy-driven profiles at a highly granular level using real-time system intelligence. Data Progression automatically migrates data to the optimum storage tier and/or RAID level based on actual use and performance needs — without manual intervention.

Using metadata, Data Progression can determine if a block is heavily accessed and how those accesses typically occur. If a block is heavily used, Data Progression can place that block on a high-performance disk. If the block is inactive, Data Progression can migrate it down to a lower cost, high-capacity disk. Unlike other arrays that require time-consuming and complex disk pool management, Data Progression automatically places the right data in the right place at the right time — for the right cost.

The traditional Compellent Data Progression model runs once a day with two primary functions:

1) Perform RAID-level migration for newly created read-only (replay) data pages to a more space efficient RAID type (typically from RAID 10 to RAID 5 or 6). This migration enables data to be written most quickly with no RAID write penalty, and then moved into the more space-efficient RAID 5 or 6. This methodology minimizes the need to use write cache to mask write latency introduced by parity calculations.

2) Move pages of data between performance and capacity disk tiers based on access frequency. More frequently accessed data is kept on a performance-optimized disk tier and less frequently accessed data is kept on a capacity-optimized disk tier. Data retained for a replay (snapshot) that is not being actively used is automatically stored on the capacity-optimized tier.

These two functions are based on the recommended profile; however you can create additional custom profile settings to meet the needs of specific applications.

SSDs — how they differ

Although flash storage can be readily substituted for HDD storage in a data center, it is fundamentally a different medium — silicon or electronic NAND gates versus magnetic media — with very different performance, cost and data retention characteristics that may impact the economics and operations of your application workloads in your data center.

The core component of an SSD is NAND flash. The two basic types of NAND flash are SLC and MLC. Unlike magnetic media on HDD storage, data stored on flash needs to be erased before new data can be written or “programmed” — this is known as the Program-Erase Cycle (PE/C). The maximum number of PE/Cs of NAND is dependent on the technology (SLC or MLC). Typically, this is in the order of a few thousand per NAND cell, after which, the performance and reliability of the flash storage cannot be guaranteed. This characteristic of flash technology limits the number of write operations that can be performed on a flash drive.
Each cell in SLC NAND is capable of storing a single “bit” of data. This enables SLC drives to write faster and achieve high cell endurance while making the drives more expensive than their MLC siblings. Cell endurance is defined as the number of times the media can be rewritten (erased and programmed).

MLC NAND, on the other hand, can store multiple “bits” per cell. This results in significantly higher memory density, thereby reducing cost. This comes at the expense of slower write speeds and significantly lower cell endurance. MLC NAND, however, still possesses exceptional random read performance.

As with hard drives, SSDs are typically developed and sold for two distinct markets: enterprise and personal storage. Enterprise-grade SSDs typically have features not found on consumer products such as non-volatile write cache, significant amounts of NAND over-provisioning, more write channels, and a 6Gb dual-ported SAS interface. All of these features are important for data integrity, high availability, and enterprise-grade performance.

The two classifications for enterprise-grade SAS SSDs that Compellent uses are write-intensive and read-intensive. The main distinctions between these drive types are their endurance specifications, capacities and cost. Compellent has been using write-intensive SSDs for more than five years, and has found that the endurance characteristics of these drives make it unlikely they will wear out during the life of a storage array. For this paper, the term write-intensive SSD refers to an SLC SSD, and the term read-intensive SSD refers to an MLC SSD.

<table>
<thead>
<tr>
<th>SSD classification</th>
<th>Cost per GB</th>
<th>Write endurance</th>
<th>Capacity</th>
<th>Write performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write intensive</td>
<td>$$$$</td>
<td>++++++++++++</td>
<td>++</td>
<td>++++++++++++</td>
</tr>
<tr>
<td>Read intensive</td>
<td>$</td>
<td>+</td>
<td>++++</td>
<td>+++</td>
</tr>
</tbody>
</table>

With the cost of SSDs continuing to decline at a faster pace than HDDs, read-intensive SSDs may soon replace 15K hard drives for high-performance storage. The issues with using a single tier of read-intensive MLC SSDs in a standard array is that there is a possibility for them to wear out in a short period of time and their write performance suffers under heavy workloads. In Compellent’s innovative approach in which two types of flash drives are deployed in a single enclosure, flash is tiered across the SLC SSDs and MLC SSDs, which have a higher capacity and lower endurance but a considerably lower price, blending the attributes of these SSDs to achieve a superior $/GB.²

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²All-flash solution under $5/Gb. Competitive US list pricing from Gartner Inc, CP Storage, as of June 2013. Market price calculated assuming a discounting of approximately 50% for all competitive systems and Dell Compellent.
Dell has made the following enhancements to improve using flash in the Compellent storage architecture:

- Rewritten core aspects of the Storage Center firmware to optimize the performance and low latency available in SSDs
- Created Flash-optimized Data Progression to leverage the endurance of write-intensive SSDs and the value of read-intensive SSDs
- Added management and monitoring capabilities specifically for flash; for example, you now have the ability to monitor wear on any SSD in the array
- Added sub-millisecond performance monitoring to the Dell Compellent Enterprise Manager and Storage Center user interfaces to provide a more precise view of flash storage performance

Features and benefits of Flash-optimized Data Progression

To optimize the benefits of both write-intensive and read-intensive SSDs, Dell added additional functionality to Compellent Data Progression specifically for use with SSDs:

- Enhanced Data Progression
- Features to maximize the performance for multiple types of SSDs
- Endurance management features
- New default storage profiles and page sizes tailored for flash
- New monitoring and management features

Whereas the traditional Data Progression algorithms would run only once each day to optimize RAID levels and data tiering, Flash-optimized Data Progression has the capability to move data across tiers throughout the day. As an example, data that has recently been frozen in a replay is now read-only and a great candidate for being moved to read-intensive tier of storage. This is all handled in the background with little to no impact to the host.
Automate tasks with storage profiles for flash-optimized solutions

The storage profile Compellent feature automates tasks that were previously done manually. A storage administrator can create a new volume and apply certain attributes to the volume to ensure the proper placement of data. For example, you can designate a volume as high priority to place on high-performance storage with the option to keep it in high-performance storage or migrate it to cost-optimized storage depending on the data's activity level. Alternatively, you can select a profile designed for backups that would place the data directly on a Tier 3, cost-optimized storage.

Storage Center 6.4 has added two new profiles in order to place data on the most appropriate types of drives, Flash Optimized and cost-optimized, or Low Priority (Tier 3), storage profiles. A Flash Optimized storage profile directs all writes to high-performance RAID 10 Tier 1 storage (flash). On-demand Data Progression automatically converts replay and read-intensive data to RAID 5 and places it on Tier 2 read-intensive flash storage that has exceptional read characteristics. A cost-optimized storage profile allows the administrator to create a volume for cost-optimized applications such as backup, archive, and low priority applications.

The Flash Optimized storage profile provides the most efficient storage for an enclosure containing both read-intensive and write-intensive SSDs. The Flash Optimized profile ensures that all write operations are carried out on write-intensive Tier 1 drives, and read operations are directed to read-intensive Tier 2 drives. If Tier 1 falls within 95% of capacity, Storage Center creates a space management replay and moves it immediately to Tier 2 to free up space on Tier 1.
The Flash Optimized disk folder and storage profile default page size is automatically set to 512KB to optimize performance in a flash-optimized solution. The default page size for a standard storage type disk folder remains at 2MB.

Flash-optimized Data Progression is designed to accommodate a number of environments:

- All-flash arrays with both read-intensive and write-intensive SSDs
- Hybrid arrays with SSDs (read-intensive and write-intensive) and spinning disks
- Arrays with only traditional write-intensive SSDs, either with or without spinning disks

In each of these cases, write data will be directed to the write-intensive SSD tier in RAID 10. This follows the model of traditional Data Progression to deliver the lowest latency writes possible. Each time a replay is taken, Flash-optimized Data Progression performs a RAID-level migration of frozen replay pages from RAID 10 to RAID 5, and then moves the RAID 5 frozen pages from the write-intensive SSD tier to the read-intensive SSD tier. To ensure that sufficient write capacity is available for RAID 10 writes in the write-intensive tier, the Compellent array takes a space management replay whenever free space on that tier drops below 5 percent.

The Flash-optimized solution is targeted at a performance-optimized workload. In the case of a flash-optimized solution made up entirely of flash with a mix of write-intensive and read-intensive SSDs, frozen read-only data pages are moved from a write-intensive SSD to a read-intensive SSD. This enables the Storage Center to deliver optimal read performance and cost effectiveness enabled by the read-intensive SSD while mitigating the wear-out disadvantages. For the flash-optimized solution, the default page size automatically changes from 2MB to 512KB. These smaller pages enable reduced bandwidth for tiering between write-intensive to read-intensive tiers.
The hybrid-flash solution with SSDs (write- and read-intensive) and spinning disks enable significantly enhanced performance while meeting more cost-sensitive price targets in a more traditional use case. As with the all-flash solution, Flash-optimized Data Progression conducts a RAID-level migration and data migration from write-intensive to read-intensive SSDs with each replay. Traditional Data Progression runs on a daily basis to tier data between the SSD tier and the spinning disk. In line with the hybrid array’s more traditional positioning, as with the all-flash array, the default page size changes to 512KB. This enables the best optimization of both SSDs and spinning media.

For customers with an existing array leveraging write-intensive SLC SSDs and spinning disks, Flash-optimized Data Progression enables the best combination of performance and space utilization in the write-intensive SSD. As with both of the other scenarios, data pages are written to RAID 10 and migrated to RAID 5 Tier 1 following each replay. Flash-optimized Data Progression helps keep the Tier 1 RAID 10 free for new incoming writes to ensure more consistent high performance for arrays with fewer SSDs. As with the hybrid array, Data Progression will run once daily to migrate data between the SSD tier and the spinning media tier(s).

**Summary**

While competitive arrays are masking back-end bottlenecks with larger and larger cache pools, Dell continues to build on its industry leading Data Progression technology. The new Flash-optimized Data Progression algorithms deliver a combination of the best features delivered by both large cache and intelligent tiering. A flash pool with Flash-optimized Data Progression provides terabytes of high-performance SSDs, leveraging read-intensive SSDs and intelligent data tiering for highly competitive cost structures.

Enhance performance in enterprise applications with improved I/O and lower latency. Dell Compellent Flash-optimized solutions’ unique way of tiering data allows you to deliver high-speed SSD performance to more applications in your environment while helping to reduce your costs significantly compared to other flash-optimized solutions.
Additional information

- Dellstorage.com/Compellent
- Dell.com/Compellent
- Storage Switzerland Lab Validation: Mixed All-Flash Array Delivers Safer High Performance
- Changing the economics of storage with Dell Compellent Flash-optimized solutions solution brief
- New economies of storage with the Compellent Flash-optimized solutions white paper
- Dell Compellent Flash-optimized Solutions spec sheet
- Dell Compellent SC200 and SC220 Enclosures spec sheet
- Dell Compellent SC280 Dense Enclosure spec sheet
- Dell Compellent Family of Products
- Efficient Storage Consolidation with Compellent solution brief
- Embracing Flash Storage executive brief

The right data in the right place at the right time — for the right cost.