NetApp® Flash Storage Portfolio Summary

Evaluation report prepared under contract with NetApp

Introduction

Flash (solid state) storage options are proliferating and are being adopted in enterprise datacenters with increasing regularity. IT professionals must be aware of the wide variety of flash-based storage solutions, and be able to determine the best fit for their applications. In those cases where mission-critical applications need the fastest performance, an all-flash storage solution can be the right choice. In other cases, a solution that uses flash as an intelligent caching layer combined with hard disk drive technology may be the best choice.

NetApp integrates flash technology across their entire line of storage systems, including the FAS, V-Series, EF-Series and E-Series product families. The solutions for the FAS and V-Series product families are part of the NetApp Virtual Storage Tier product family.

The intelligent caching available today includes:

- Flash Cache controller caching using PCIe devices for FAS and V-Series
- Flash Pool SSD caching for FAS and V-Series (NetApp disk shelves only)
- SSD Cache for E-Series systems

The all-flash solutions available today include:

- EF540 and EF550 flash arrays, part of the EF-series product family

NetApp commissioned Demartek to evaluate these technologies by running various performance tests, and these reports are available on the Demartek website. This document provides a summary of the architectures of the NetApp flash solutions available today and the new FlashRay™ family expected to become available in 2014.

NetApp Intelligent Caching

The intelligent caching functions for the NetApp FAS, V-Series and E-Series product families include Flash Cache and Flash Pool, as shown in the following diagram.

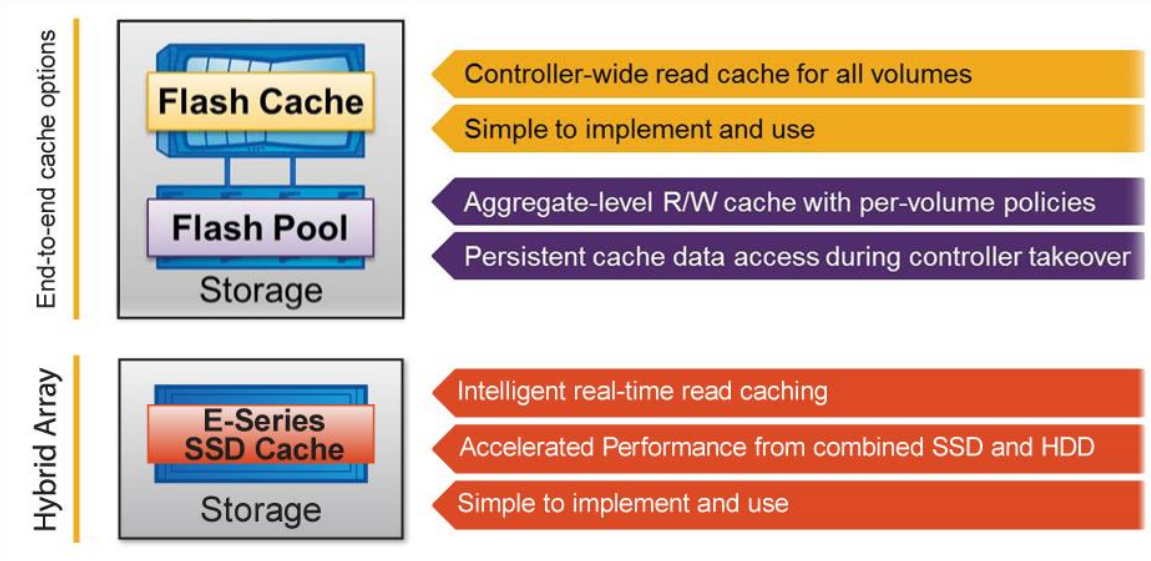

Figure 1 – NetApp Intelligent Caching Solutions

NetApp EF-Series All-flash

The NetApp EF-Series product family deploys flash in all-flash storage systems, also known as all-flash arrays (AFAs), as shown in the following diagram.

Figure 2 - NetApp EF-Series Product Family

Data Placement – Flash as Cache vs. Primary Storage

Once a decision has been made to incorporate flash technology into an enterprise, the next major decision focuses on how to use this flash technology, or more specifically, how to place data on these devices. There are two general ways to use flash technology: for primary storage or for caching. Both methods are effective at improving I/O performance.

Flash as Primary Storage

When SSDs are used as primary storage, the following observations can be made:

- The administrator (or user) decides which data to place on the solid state storage.
- The administrator decides when to place the data on the solid state storage.
- The administrator is responsible for adjusting applications and backup configurations in order to find the data at its new location.
- Only the applications whose data resides on the solid state storage gain a performance improvement.
- The performance gains are immediate.

In order for the user to determine which data should be placed on the solid state storage, some sort of decision or ranking process must be performed. This can include ranking the most performance-sensitive applications, considering the amount of high-speed storage capacity needed, and determining the effects of the improved performance to the overall business or operation.

Flash as a Cache

When flash technology is used as a cache, the following observations can be made:

- The caching solution places a copy of "hot" data into the cache.
- The caching solution decides when to place the copy of the hot data into the cache.
- Multiple applications can gain a performance benefit.
- The aggregate performance gains occur over time as the cache "warms-up."
- Applications do not need to be modified to take advantage of the cache.
- Some caching solutions only cache reads, others cache both reads and writes.
- Management of a caching solution is relatively simple.

Caching algorithms vary from product to product, but generally intelligent caching solutions perform very well with random I/O workloads. Also, when caching solutions are deployed and as the cache warms, the remaining I/O activity on the back-end HDDs is reduced, allowing the HDDs to perform better.

Flash Cache

Flash Cache is another, more familiar, key component of the NetApp Virtual Storage Tier (VST). It is a solution that combines software and hardware within NetApp storage controllers to increase system performance without increasing the disk drive count. Flash Cache is implemented as software features in Data ONTAP® and PCIe-based modules with 512GB, 1 TB or 2TB of Flash memory per module. Flash Cache cards are controlled by custom-coded field programmable gate arrays (FPGAs). Multiple modules may be combined in a single system and are presented as a single unit. Flash Cache improves performance for workloads that are random read intensive such as file services, messaging, OLTP databases, and server/desktop virtualization. Up to 16TB of read cache in a storage system can be configured using Flash Cache cards. The ability to cache large quantities of active data makes Flash Cache cards effective across a broad set of workloads.

Flash Cache Operations

In Data ONTAP prior to Flash Cache, when a client or host needed data and it wasn't currently in the buffer cache in system memory, a disk read resulted. Essentially, the system asked itself if it had the data in RAM, and, if the answer was no, it went to the disks to retrieve it. When more space was needed in memory, Data ONTAP analyzed what it currently held and looked for the lowest priority data to clear out to make more space. Depending on the workload, this data could have resided in the buffer cache for seconds or hours; either way it had to be cleared.

With the addition of Flash Cache, the data that would have previously been cleared is now placed in Flash Cache. Data is always read from disk into memory and then stored in Flash Cache when it needs to be cleared from the buffer cache.

Now that the data is stored in Flash Cache, Data ONTAP can check to see if the data is there the next time it is needed. When it is there, access to it is far faster than having to go to disk. This is how a workload is accelerated.

An important aspect regarding the operation of Flash Cache is that it is a read cache. Flash Cache is designed to accelerate read performance only. Data ONTAP is already optimized for writes, and Flash Cache technology is not meant to improve them. Some benefit might be observed with write-intensive workloads because disk utilization might decrease due to read operations being handled by Flash Cache instead of going to disk.

Flash Pool

NetApp Flash Pool is a storage cache option within the NetApp Virtual Storage Tier product family, available for NetApp FAS storage systems. A Flash Pool configures solid state drives (SSDs) and hard disk drives (HDDs) into a single storage pool, known as an "aggregate" in NetApp parlance, with the SSDs providing a fast response time cache for volumes that are provisioned on the Flash Pool aggregate.

In a NetApp Flash Pool aggregate, the SSDs are used to cache data for all volumes that are provisioned on that aggregate. Flash Pool is specifically targeted at accelerating repeat random read operations and off-loading small-block random overwrite operations (which are a specific class of writes) from HDDs. Although a Flash Pool SSD cache is a single entity within the aggregate, for the purposes of configuration and cache data management the read cache and write cache are two separate entities.

Flash Pool Read Caching

Flash Pool caches random read requests of all sizes. Caching of random reads significantly improves read I/O response times for the volumes provisioned in a Flash Pool that have read caching enabled. It is possible to exclude volumes from using the Flash Pool read cache.

Flash Pool Write Caching

Flash Pool write caching is targeted at caching overwrites of random data where the operation size is 16KB or smaller. Caching small-block random overwrites off-loads write operations that can consume many HDD I/O cycles on data that will soon be invalidated by the next overwrite.

The Flash Pool does not accelerate normal writes, as the Data ONTAP® operating system is already write-optimized through the use of write cache and non-volatile memory (NVRAM or NVMEM).

E-Series SSD Cache

The NetApp E-Series SANtricity® solid state drive (SSD) cache feature, available beginning with NetApp SANtricity 10.84 software, uses SSD storage to hold frequently accessed data from user volumes. The primary principle behind the SSD Cache feature is that a copy of "hot" data is placed in the cache, and repeated accesses to this data are accelerated, because they can be serviced from the SSD Cache instead of the slower HDD technology. However, because this data is a copy, the original data is fully protected by all the standard features provided by the storage system. The SSD capacity supported for the SANtricity SSD cache feature ranges from 1TB to 5TB, and is based on the amount of DRAM memory per controller.

SANtricity SSD cache improves performance for workloads that have the following characteristics:

- A high percentage of reads relative to the number of writes
- A large number of reads that are repeated to the same or adjacent areas
- The size of the working set of repeated accesses is smaller than the SSD cache
- Read performance to the HDDs only is constrained by the HDDs

SANtricity SSD Cache Operations

The SSD cache is a secondary cache that is used with the I/O controller's primary cache contained in the controller's DRAM. In controller cache, the data is stored in DRAM after a host read. In SSD cache, the data is copied from user-specified base volumes and stored on two internal RAID 0 volumes (one per controller) that are automatically created when an SSD cache is created. These volumes are used for internal cache processing and are not accessible to the user or displayed in the user interface.

The SSD capacity is divided into cache blocks and subblocks in a manner similar to the DRAM cache, except that the SSD cache blocks are much larger than the DRAM cache blocks. A portion of DRAM is reserved for SSD cache block management.

SANtricity SSD cache is designed to allow the user to select the type of I/O operations that are cached. This user-selectable I/O type controls the SSD cache settings for the cache block size, subblock size and other SSD cache management settings. These I/O types are database, file system and web server. Each has its own settings that affect the SSD cache block size and other related cache management settings. These I/O types are guidelines to help provide optimal performance, but some workloads may perform better with different settings, depending on the exact I/O pattern for that workload.

The SANtricity SSD cache participates in data assurance (DA) operations such as T10/PI support. The SSD cache does not currently support full disk encryption (FDE) because the FDE-capable SSDs are not yet available.

SANtricity SSD cache contains a built-in performance modeling tool that provides the SSD cache hit percentage, average latency and several other metrics. This tool can help the user or administrator determine the optimum SSD cache settings.

EF-Series All-Flash Storage

The NetApp EF-Series is an enterprise storage system designed for performance-driven applications that also need consistent low latency. It has a dual-controller architecture that has dedicated links between the controllers for inter-controller communications and supports a variety of host interfaces including Fibre Channel, SAS, iSCSI and InfiniBand. All the components of an EF-Series array are fully redundant and hot-swappable, including controllers, disk drives, power supplies and fans. Additionally, controller firmware upgrades can be performed non-disruptively.

The internal quad-core processors include integrated high-speed RAID engines that support RAID levels 0, 1, 5, 6 and 10 with global hot spares or the array can be configured with Dynamic Disk Pools which simplifies management and expands functionality. The controller's PCI express buses between the processor and external interfaces provide enough capability to handle large-block I/O and the speed to process large amounts of random, small-block I/O. Each EF-series array provides 24GB of memory, which is battery-backed and de-staged to internal flash upon power loss.

The EF-Series array comes in a 2U chassis supporting 24 drives and can be expanded to a total of 120 drives.

The EF-Series has been shown to deliver as many as 400,000 IOPS with sub-millisecond latency. With this type of performance, it is suitable for any workload where it is imperative to deliver data to end users or application consistently with minimal delay. Some of these environments include database, web services, virtual desktop infrastructure (VDI) and others.

FlashRay All-Flash Storage

NetApp plans to deliver its new FlashRay platform in 2014. The FlashRay architecture is being built from the ground up to maximize the capabilities of flash and combine low-latency performance with the classic NetApp values of integrated data protection and built-in efficiencies. FlashRay is designed to scale-out, support multiple protocols, and will provides enterprise storage efficiency features such as global inline deduplication and compression.

Summary and Conclusion

Solid state storage technology is gaining acceptance in enterprise datacenters and becoming integral to modern datacenters, especially those that seek significant improvement in transactional response time or overall time to complete work. NetApp offers a full portfolio of flash-based storage solutions that can satisfy high performance and very low latency requirements.

NetApp's solutions include storage system caching and all-flash storage arrays that are well-suited to many workload environment requirements. These solutions provide significant performance advantages while providing enterprise-class reliability and world-wide support. The NetApp solid state storage technologies build on NetApp's strength in storage capacity efficiency while helping reduce power consumption in datacenters.

We recommend that IT managers and administrators consider the NetApp portfolio for applications requiring the use of flash technology.

The most current version of this report is available at http://www.demartek.com/Demartek_NetApp_Flash_Storage_Portfolio_2014-01.html on the Demartek website.

NetApp, the NetApp logo, Flash Cache, Flash Pool, FlashRay, and SANtricity are trademarks or registered trademarks of NetApp, Inc. in the United States and/or other countries.

Demartek is a registered trademark of Demartek, LLC.

All other trademarks are the property of their respective owners.