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JetStor X Series White Paper

SSD Cache 2.0

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824FXD	Dual Controller	LFF 24-disk 4U Chassis
824iXD	Dual Controller	LFF 24-disk 4U Chassis
824FX	Single Controller	LFF 24-disk 4U Chassis
824iX	Single Controller	LFF 24-disk 4U Chassis

JetStor X Series Storage System 3U 19” Rack Mount Models

Model Name	Controller Type	Form Factor, Bay Count, and Rack Unit
816FXD	Dual Controller	LFF 16-disk 3U Chassis
816iXD	Dual Controller	LFF 16-disk 3U Chassis
816FX	Single Controller	LFF 16-disk 3U Chassis
816iX	Single Controller	LFF 16-disk 3U Chassis

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812FXD	Dual Controller	LFF 12-disk 2U Chassis
812iXD	Dual Controller	LFF 12-disk 2U Chassis
812FX	Single Controller	LFF 12-disk 2U Chassis
812iX	Single Controller	LFF 12-disk 2U Chassis
826FXD	Dual Controller	SFF 26-disk 2U Chassis
826iXD	Dual Controller	SFF 26-disk 2U Chassis

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SSD Cache 2.0

Executive Summary

SSD cache is a large-capacity secondary cache that uses enterprise SSD drives positioned between the RAID controller's primary DRAM memory cache and hard disk drives (HDD). SSD read cache extends the RAID controller's existing memory cache capacity and functionality by copying frequently accessed data to SSD drives, which are faster than HDDs, therefore boosting system-wide performance. However, SSD write cache buffers write I/O to improve overall IOPS. By this technology, QCache 2.0 can improve random read performance by up to 92 times and random write by up to 147 times.

SSD cache is a licensed feature available on the JetStor X Series. This document discusses the SSD cache technology and describes its features, functions, management, and best practice.

INFORMATION:
SSD cache 2.0 with read and write cache is available in SANOS firmware 1.1.0.

Audience

SSD cache function needs system memory to store metadata. The usable capacity of SSD cache is in proportion to the size of the controller system memory. The following table is the relationship between the system memory per controller and the maximum SSD cache capacity.

Table 1 The Relationship between System Memory and SSD Cache Capacity

System Memory per Controller	Maximum SSD Cache Capacity per System
4GB	X (No Support)
8GB ~ 15GB	2TB
16GB ~ 31GB	4TB
32GB ~ 63GB	8TB
64GB ~ 127GB	16TB
128GB	32TB

CAUTION:
SSD cache function is not supported when the system memory is under 8GB per controller.

The SSD cache is optional; the SSD cache license can be extended to SSD cache 2.0 with read and write cache. The data structure of the SSD cache 2.0 is re-designed from the previous SSD cache. After upgrade to firmware 1.1.0 with SSD cache 2.0, you have to configure SSD cache again if you have already enabled SSD cache in firmware 1.0.x.

CAUTION:
Execute COLD REBOOT after upgrade from firmware 1.0.x to 1.1.0.

Notice that it CAN NOT be downgraded to firmware 1.0.x after upgrade to 1.1.0.

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Overview

Traditionally, data has been stored on traditional rotating memory, or HDDs (Hard Disk Drives) and SSDs (Solid-State Drives) are mainly used for mission-critical applications that demand high-speed storage systems, however tend to be costly. In recent years, the

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capacity of HDDs has increased, but their random I/O (Input / Output) has not kept pace. For some applications such as web commerce, clouds, and virtualization that require both high capacity and performance, HDDs, though capacious, simply are not fast enough and SSDs have increased capacity and have declined in cost, making them more attractive for caching in SAN storage networks.

Smart Response Technology (also known as SSD cache technology) leverages the strengths of both HDDs and SSDs, to cost-effectively meet the capacity and performance requirements of enterprise applications. Data is primarily stored on HDDs while SSDs serve as an extended HDD memory cache for many I/O operations. One of the major benefits of using SSD cache is the improved application performance, especially for workloads with frequent I/O activity. The read data of an application that is frequently accessed is copied to the SSD cache; the write data is stored to the SSD cache temporary and then flush to HDDs in bulk. So the application receives an immediate performance boost. JetStor SSD cache enables applications to deliver consistent performance by absorbing bursts of read/write loads at SSD speeds.

Another important benefit is improved TCO (Total Cost of Ownership) of the system. SSD cache copies the hot or frequency of data to SSDs in chunks. By offloading many if not most of the remaining IOPS after SSD cache, the user can fill the remainder of their storage needs with low cost, high capacity HDDs. This ratio of a small amount of SSD paired with a lot of HDD offers the best performance at the lowest cost with optimal power efficiency.

Generally, SSD read cache is particularly effective when:

- Reads are far more common than writes in the production environment, common in live database or web service applications.
- The inferior speeds of HDD reads cause performance bottlenecks.
- The amount of repeatedly accessed data is smaller than the capacity of the SSD cache.

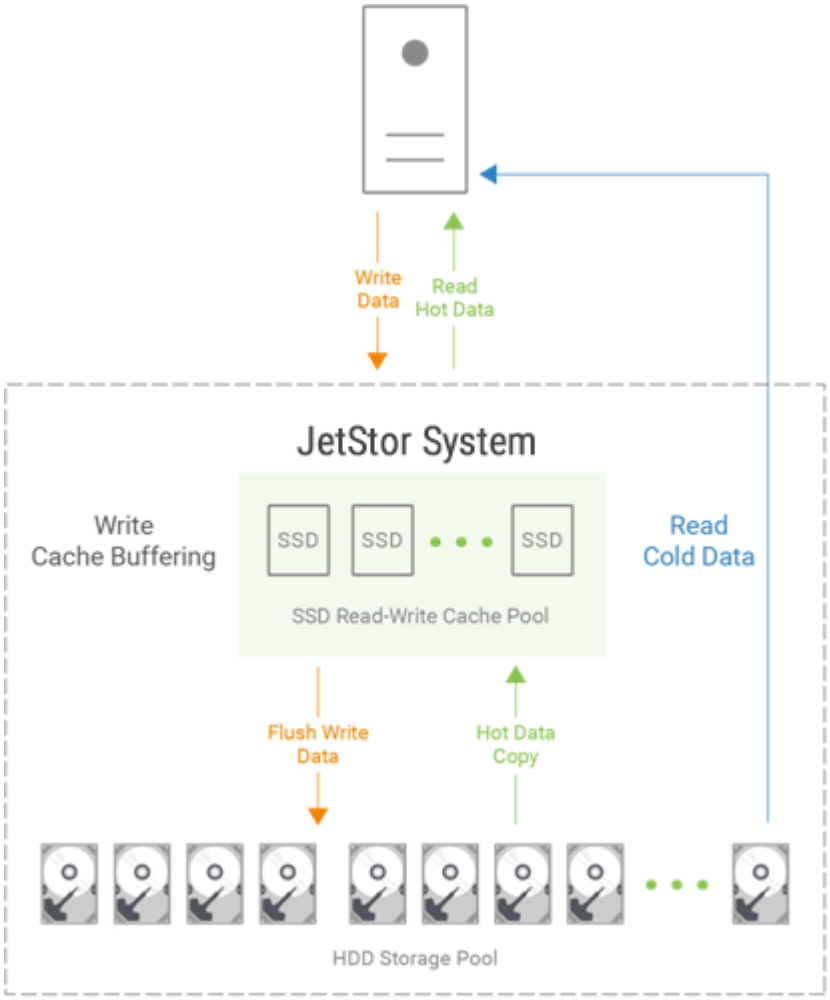

Figure 1 SSD Read and Write Cache

SSD read-write cache is particularly effective when:

- Reads and writes mix in the production environment, common in file service applications.
- The inferior speeds of HDD reads and writes cause performance bottlenecks.
- Same as SSD read cache case; the size of repeatedly accessed data is smaller than the capacity of the SSD cache.
- Willing to take a little risk to increase write performance because it's write cache buffering at SSD cache pool. Of course, these write data in SSD cache can be used at the next read.

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Theory of Operation

SSD cache allows an SSD to function as read cache or write buffer for a HDD volume. In SSD read cache, it is a secondary cache that improves performance by keeping frequently accessed data on SSDs where they are read far more quickly than from the HDD volume. When reads or writes are performed, the data from the HDDs are copied into the SSD cache. Although the data is duplicated to SSD cache pool, it does not matter if the read cache pool is corrupted.

In SSD write cache, SSDs are a write buffering storage that improves performance by storing the write data in SSDs temporary where they are write far more quickly than to the HDD volume. And then the write data will be flushed to the HDD volume at the appropriate time. It may take risk of losing data during the period that the write data is stored in SSD cache if the SSD cache pool is corrupted. The write data has not yet written back to the HDD volume. So the read-write cache pool needs data protection to protect the write data.

CAUTION:
Using SSD read-write cache may take risk of losing data if the SSD cache pool is corrupted. User has to monitor the health of the SSD cache pool carefully.

SSD Cache Pool Architecture

A SSD cache pool is grouped to provide capacity for SSD cache usage of a dedicated storage pool. The maximum SSD cache pool quantity per system (either dual controller or single controller) is 4. The following is the storage architecture of SSD cache pool.

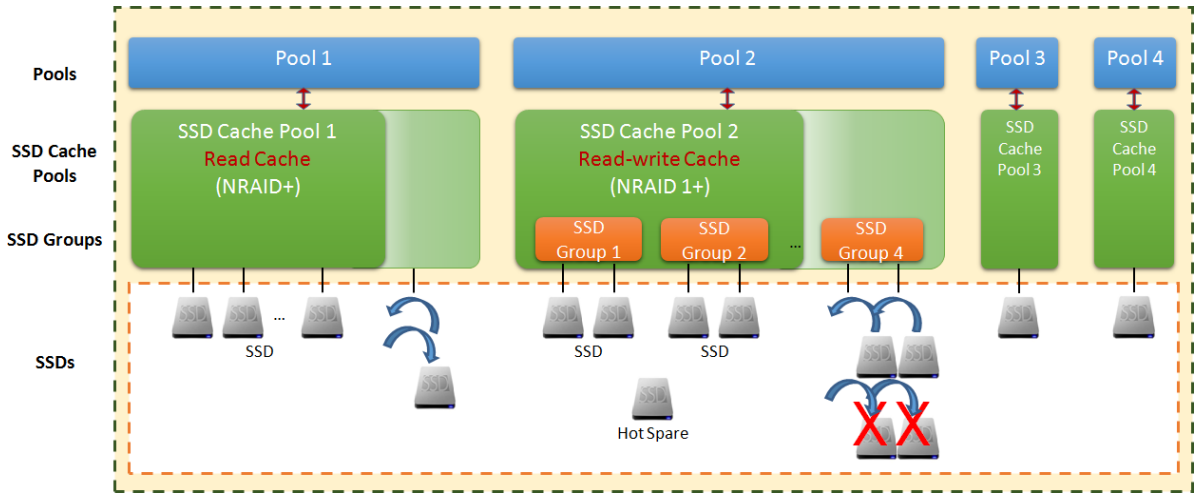

Figure 2 Storage Architecture of SSD Cache Pool

Take an example of SSD read cache; one or more SSDs with NRAID+ (which is described in the next section) are grouped into the "SSD Cache Pool 1" and assigned to the "Pool 1" for use. The maximum SSD quantity in an SSD cache pool is 8. When the SSD read cache is performing, the capacity of the SSD cache can be increased by adding an SSD or decreased by removing an SSD.

Another example of SSD read-write cache; two SSDs with NRAID 1+ (which is also described in the next section) are grouped into an SSD group. One or more SSD groups combine to the "SSD Cache Pool 2" and assigned to the "Pool 2" for use. When the SSD read-write cache is performing, the capacity of the SSD cache can be increased only by adding an SSD group with two SSDs at a time. The SSD read-write cache pool can set SSDs as dedicated hot spares. The maximum dedicated spare SSD quantity in an SSD cache pool is 4. The following table is the summary of the SSD cache parameters.

Table 2 SSD Cache Parameters

Item	Value
Maximum SSD cache pool quantity per system (either dual controller or single controller)	4
Maximum SSD quantity in an SSD cache pool	8
Maximum capacity of an SSD cache pool	32TB
Maximum quantity of volume shared in an SSD cache pool	32
Maximum dedicated spare SSD quantity in an SSD cache pool	4

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TIP:
Note that the capacity allocated to the SSD cache pool is not counted in the regular data storage.

The volumes in pool can be selected to enable SSD cache function. The following is the relationship between SSD cache pool and storage pool.

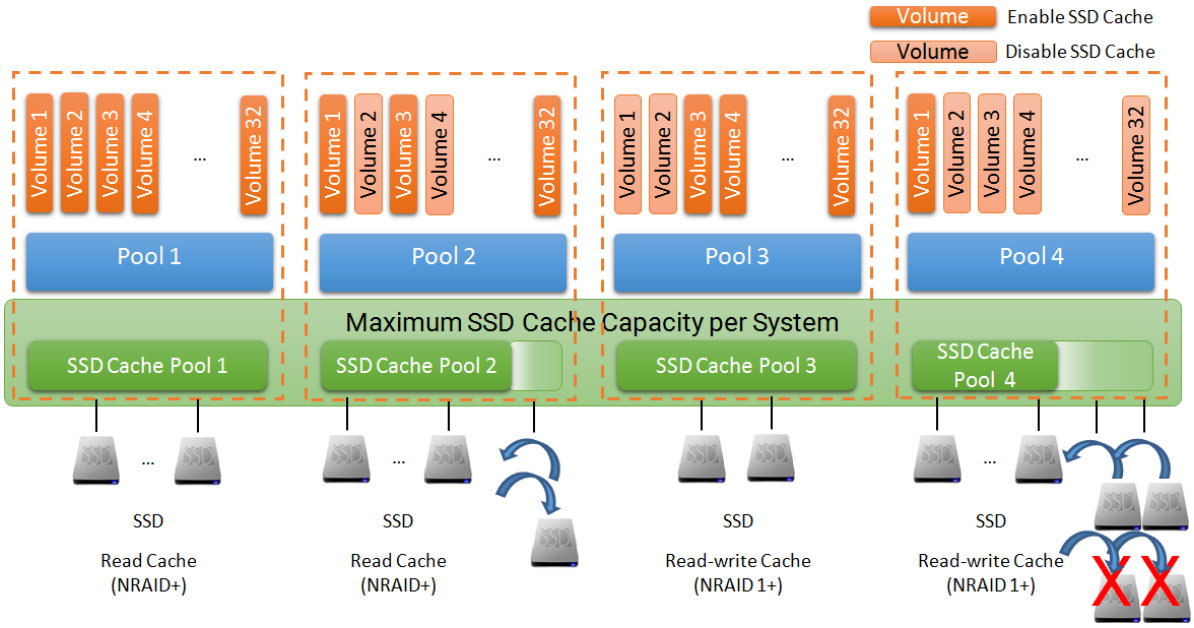

Figure 3 The Relationship between SSD Cache Pool and Storage Pool

The volumes enabled SSD cache with hot data will consume the capacity of the SSD cache pool. Users have to consider which volumes are enabled according to the SSD cache resources. When the SSD cache is performing, you can enable or disable the volume. The maximum quantity of volume shared in an SSD cache pool is 32.

RAID Level of SSD Cache Pool

SSD read cache with NRAID+

Generally, SSD read cache uses NRAID (Non-RAID) or RAID 0 without data protection to create the SSD cache storage space. Our SSD read cache technology uses NRAID+ which is parallel NRAID without striping.

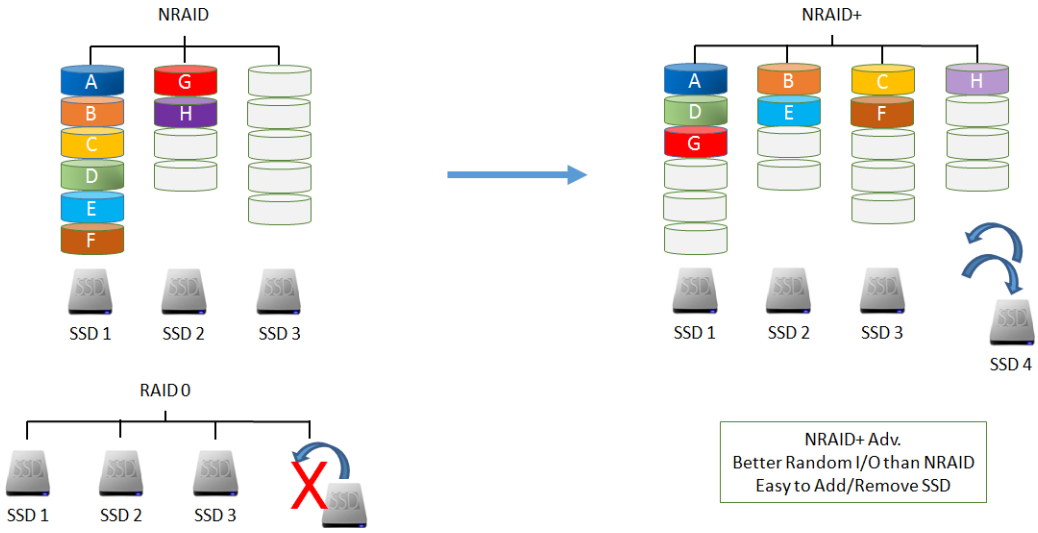

Figure 4 SSD Read Cache with NRAID+

NRAID is a method of combining the free space on multiple disk drives to create a spanned capacity. A NRAID is generally a spanned volume only, as it can contain disk drives of various types and various sizes. RAID 0 consists of stripes, without mirroring or parity. Adding a disk drive into RAID 0 needs to re-stripe the data. For SSD cache, it will have terrible performance when performing SSD cache and migrating RAID 0 at the same time. Let alone remove a disk drive.

Compare to the NRAID or RAID 0, NRAID+ distributes cache data over all SSDs. This NRAID+ technology combines with the advantages of NRAID and has better random I/O than NRAID. It also has the advantage of easy to add/remove SSDs from the SSD cache pool to increase/decrease the capacity.

Although the SSD read cache is a technique of duplicating data. If the SSD cache pool corrupts, the original data will be safe but stop SSD read cache.

SSD read-write cache with NRAID 1+

SSD read-write cache needs data protection, so it usually uses RAID 1 or RAID 10 level to create the SSD cache storage space. Our SSD read-write cache technology uses NRAID 1+ which is parallel NRAID with mirror.

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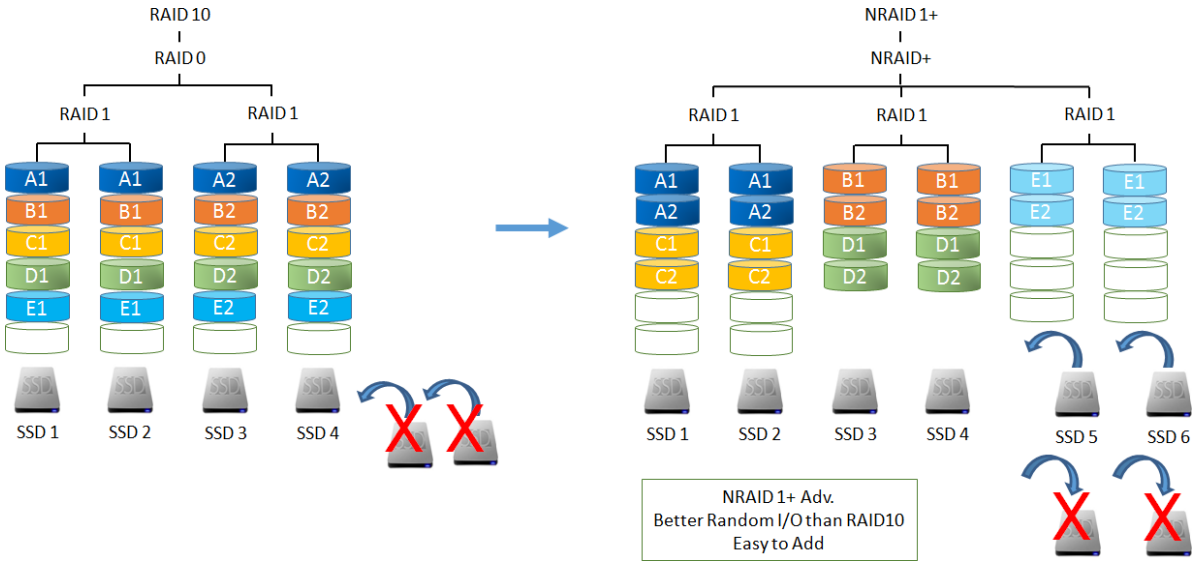

Figure 5 SSD Read-write Cache with NRAID 1+

RAID 10 creates a striped set from a series of mirrored drives. The same, adding pair disk drives into RAID 10 needs to re-stripe the data. So it is hard to add SSDs into SSD cache pool.

Compare to the RAID 10, NRAID 1+ distributes cache data over all mirrored SSDs. This NRAID 1+ technology has the data protection and better random I/O than RAID 10. It also has the advantage of easy to add SSDs into the SSD cache pool to increase the capacity. In this case, we disallow the SSDs to be removed from the SSD cache pool because it has the risk of losing write cache data.

If one SSD failure occurs in the SSD cache pool, the status of the SSD cache pool will be changed to degrade. It will stop write cache and start flushing write cache data into HDDs. At this time, read cache data is still working but no more new read cache data will be added into SSD cache pool. The SSD read-write cache pool can set SSDs as dedicated hot spares to prevent SSD cache pool failure. After inserting an SSD as a hot spare, the SSD read-write cache pool will be rebuilt until it is completed. And then it reverts to SSD read-write cache service.

Read/Write Cache Cases

The following describes the cases of read/write cache. In SSD read cache, the processes of read/write data will be disassembled to the following cases.

- Read Data with Cache Miss

- Read Data with Cache Hit
- Write Data in SSD Read Cache

Besides, in SSD read-write cache, the processes of read data are the same as above. But the write data is different. The processes of write data will be described on following case.

- Write Data in SSD Read-write Cache

Each case will be described below.

Read Data with Cache Miss

The following figure shows how the controller handles a host read request when some or all of the data are not in the SSD cache.

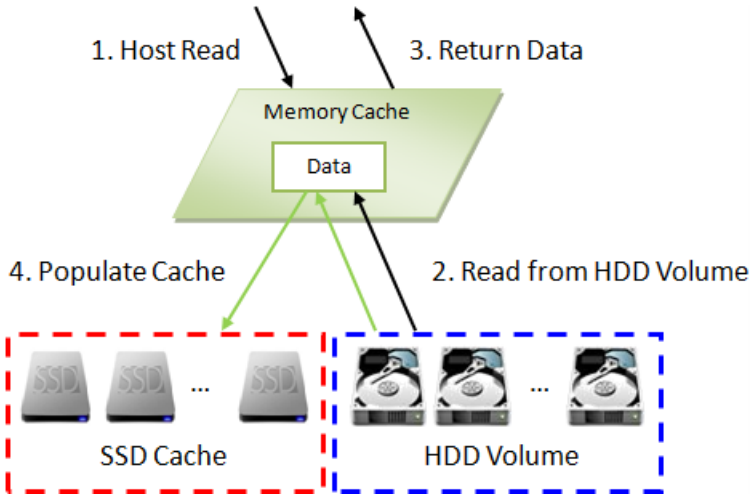

Figure 6 Read Data with Cache Miss

These steps are:

1. A host requests to read data. The system will check if the requested data is in memory cache or SSD cache. If not, it is called cache miss.
2. Data is read from the HDD volume because of cache miss.
3. The requested data is returned to the host. And the system will check whether the requested data is hot data.
4. If it is, the SSD cache is populated.

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INFORMATION:
The actions that read data from the HDD and then write to the SSD are called populating the cache. For more information, please refer to Populating the Cache in the next section.

Read Data with Cache Hit

The following figure shows how the controller handles a host read request when the data is in the SSD cache.

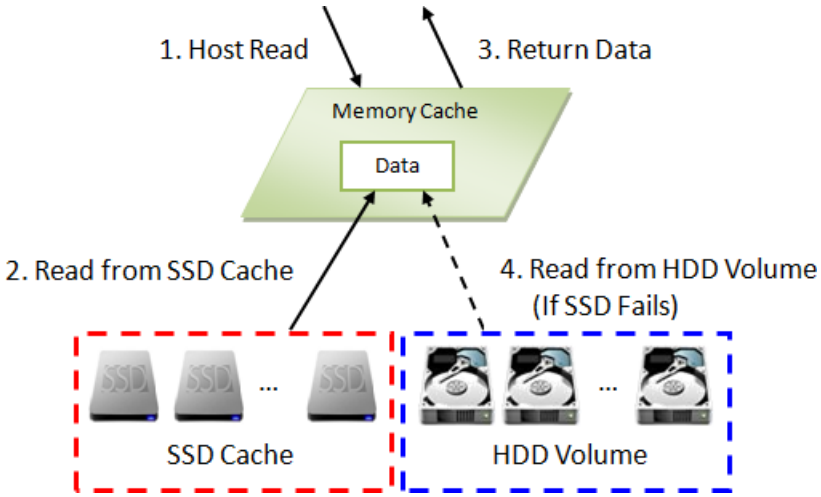

Figure 7 Read Data with Cache Hit

These steps are:

1. A host requests a read data. The system finds that the data is in SSD cache, so it is called cache hit.
2. Data is read from the SSD cache.
3. The requested data is returned to the host.
4. If there is an SSD cache error, data is read from the HDD volume.

Write Data in SSD Read Cache

The following figure shows how the controller handles a host write request in SSD read cache. The write data can also be frequently accessed data and populated into SSD cache for next read.

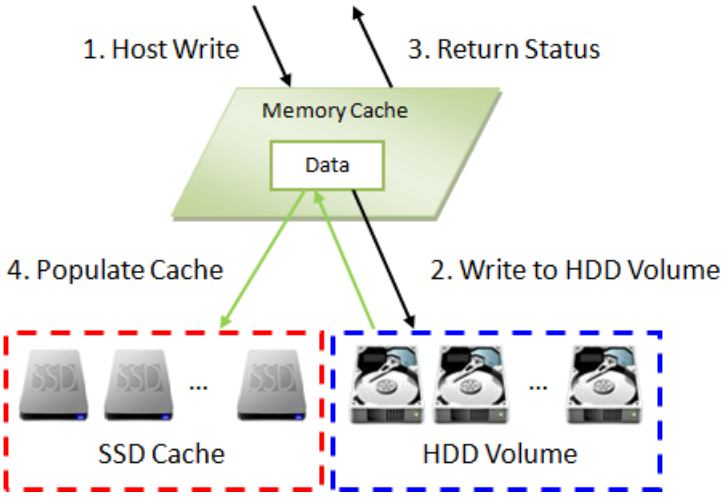

Figure 8 Write Data in SSD Read Cache

These steps are:

1. A host requests to write data.
2. Data is written to the HDD volume.
3. The status is returned to the host.
4. The SSD cache is populated if the write threshold is reached.

Write Data in SSD Read-write Cache

The following figure shows how the controller handles a host write request in SSD read-write cache. The write data stays in the SSD cache for a while, and will be flushed to the HDD volume at the appropriate time.

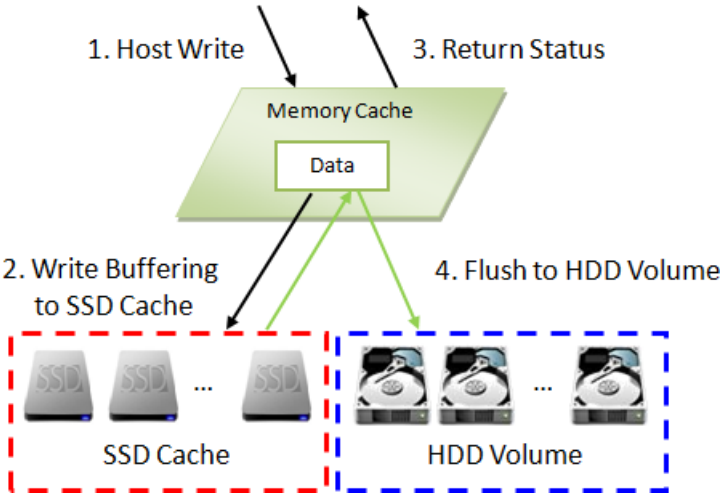

Figure 9 Write Data in SSD Read-write Cache

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These steps are:

1. A host requests to write data.
2. Data is written to the SSD cache.
3. The status is returned to the host.
4. Data will be flushed to the HDD volume at the appropriate time.

Flush Write Data to HDD Volume

In SSD read-write cache, the write data will be flushed to the HDD volume in the following situations.

- Flush data to the HDD volumes before the SSD cache pool is deleted.
- Flush data to the HDD volumes before the related volume is disabled.
- Flush data when the system is idle.

CAUTION:
It will take time to flush data from SSD cache to HDD volumes. Please do not remove SSDs before complete flushing; otherwise it may take risk of losing data.

In addition, to avoid taking a long time to complete flushing, please make sure the front I/O traffic is not heavy when deleting SSD cache pool.

TIP:
It won't flush data to the HDD volumes when system goes shutdown or reboots.

Populating the Cache

The actions that read data from the HDD and then write to the SSD are called populating the cache. Typically, this is a background operation that immediately follows a host read or write operation. As the goal of the cache is to store frequently accessed data, not every I/O operation should trigger a cache population, but only ones that pass a certain threshold, implemented as a counter. There are both a populate-on-read threshold, and a populate-on-write threshold.

Populate-on-read Threshold

When the same data block to be read over the threshold, it is called hot data and is populated to the SSD cache. The threshold must be greater than or equal to 1 in SSD read cache or SSD read-write cache. The value is forbidden to set 0 because of no action in read cache. The maximum of the threshold is 4. If larger than 4, the frequently accessed data is hard into SSD cache, so there is no obvious effect.

Populate-on-write Threshold

When the same data block to be written over the threshold, it is called hot data and populated to the SSD cache. The threshold must be greater than or equal to 0. If it is set to 0, no action is performed for a write cache. The value must be greater than or equal to 1 in SSD read-write cache. The value is forbidden to set 0 because of no action in write cache. The same as above, the maximum of the threshold is 4. If larger than 4, there is no obvious effect.

Operation Process

Each cache block on a HDD volume has a read and write counter associated. When a host requests to read data located in that cache block, the read count is increased. If the data is not found in the cache and the read count is greater than or equal to the populate-on-read threshold, then a cache-populate operation is performed concurrently with the host read operation. If a cache hit occurs, the data is immediately returned from the SSD cache and a populate operation is not performed. If the read count is smaller than the threshold, a populate operation is not performed.

Write cases are the same scenario as read.

SSD Cache Tuning

The SSD cache can be tuned to maximize its efficiency base on application usage. Cache block size, populate-on-read threshold and populate-on-write-threshold are the main parameters.

Cache Block Size

A large cache block suits applications where frequently accessed data is close to each other, known as a high locality of reference. A large cache block will also fill up the SSD cache quickly - this is known as the warm-up time. After the cache is warmed up, the performance would be quite good for applications with high locality of reference. Such as

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the file system or web service usage, the frequently accessed data are based on some concentrated files which are usually in large block size. However large cache blocks will also generate larger I/O overhead, increasing response time, especially for cache misses.

A smaller cache block size suits applications with data that is less localized, meaning the data is accessed more randomly, such as database usage. The SSD cache will fill up slower, but with more cache blocks, there is greater chance of a cache hit, especially for data with less locality of reference. With a smaller cache block size, cache usage is usually less than with a larger cache block size, but overhead is less, so the penalty for cache misses is less severe.

Population Threshold

The population threshold is the quantity of accesses at which point that cache block is copied to the SSD Cache. A higher number ensures that the cache only stores frequently accessed data so there will not be much cache turnover however it also means the cache will take longer to warm up and be fully effective. A lower number means the cache is warmed up quickly, but may cause excessive cache populations. A populate on read threshold of 2 is sufficient for many applications. Populate-on-write is useful when data that is written to is often read soon after. This is often the case in file systems. Other applications, such as database software, does not have this tendency so populate on write may sometimes even be disabled.

Table 3 I/O Type Table for SSD Read Cache

I/O Type	Block Size (Sectors)	Populate-on-Read Threshold	Populate-on-Write Threshold
Database	1MB (2,048)	2	0
File System	2MB (4,096)	2	2
Web Service	4MB (8,192)	2	0
Customization	1MB/2MB/4MB	≥ 1 and ≤ 4	≥ 0 and ≤ 4

Table 4 I/O Type Table for SSD Read-write Cache

I/O Type	Block Size (Sectors)	Populate-on-Read Threshold	Populate-on-Write Threshold
Database	1MB (2,048)	2	1
File System	2MB (4,096)	2	1
Web Service	4MB (8,192)	2	1
Customization	1MB/2MB/4MB	≥ 1 and ≤ 4	≥ 1 and ≤ 4

As you can see, there are tradeoffs for increasing or decreasing each parameter. Understanding the data locality of the application is essential and it can be useful to do some field testing to see what works best.

Configure SSD Cache

The **SSD Cache** provides **SSD Cache Pools** and **SSD Cache Statistics** function tabs to configure and monitor SSD cache. This section will describe the operations of configuring SSD cache.

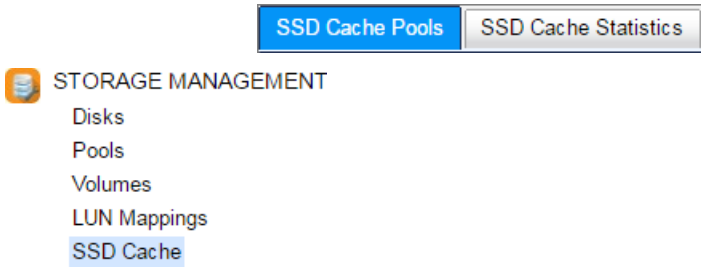

Figure 10 SSD Cache Function Submenu

Enable SSD Cache License

The SSD cache function is optional. Before using it, you have to enable SSD cache license. Select the **Update** function tab in the **Maintenance** function submenu, download **Request License** file and send to your local sales to obtain a License Key. After getting the license key, click the **Choose File** button to select it, and then click the **Apply** button to enable. When the license is enabled, please reboot the system. Each license key is unique and dedicated to a specific system. If you have already enabled, this option will be invisible.

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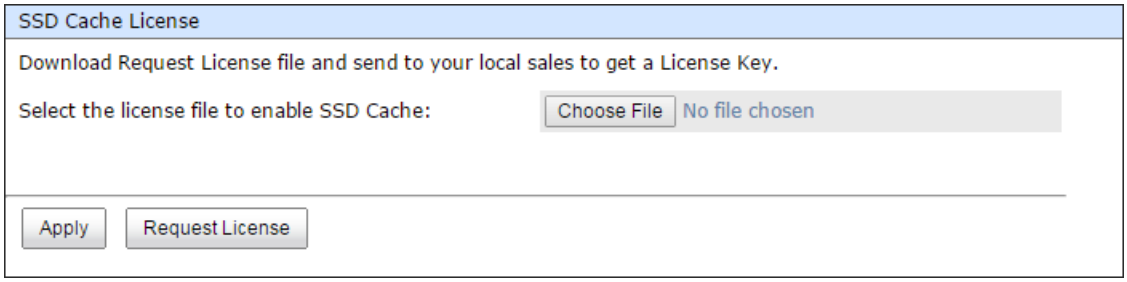

Figure 11 Enable SSD Cache License

Create an SSD Cache Pool

Here is an example of creating an SSD cache pool with 2 SSDs configured in SSD read cache.

1. Select the **SSD Cache** function submenu; click the **Create SSD Cache Pool** button. It will scan available SSDs first.

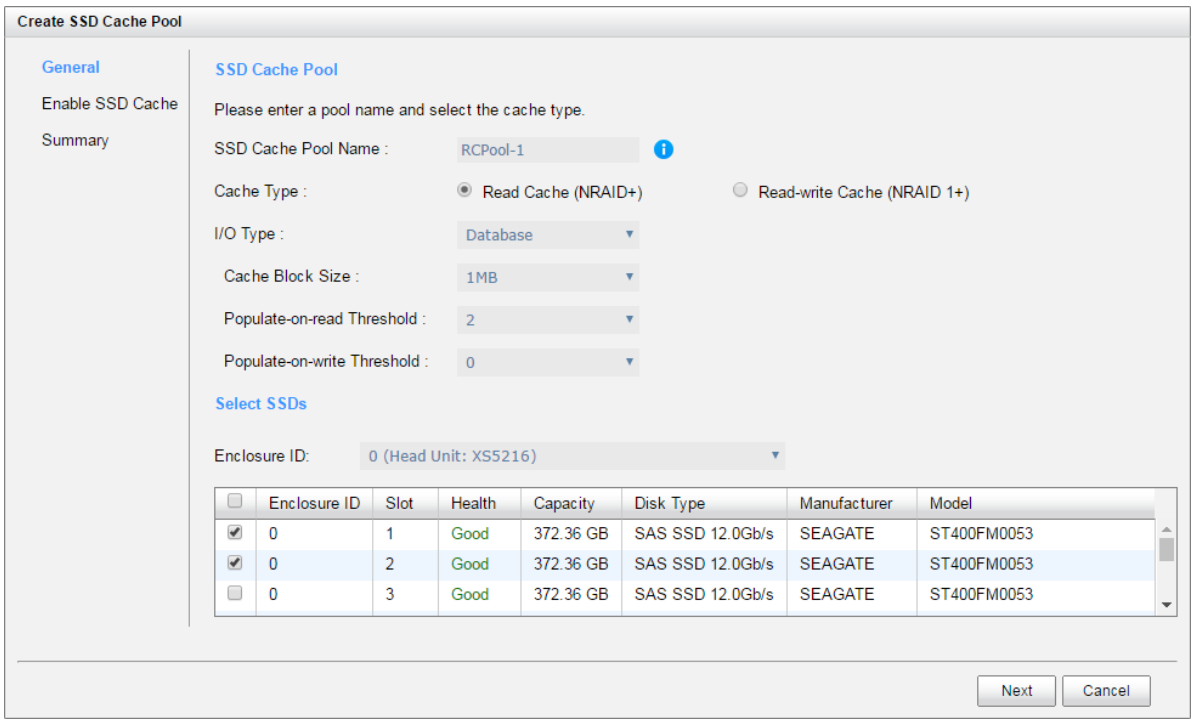

Figure 12 Create an SSD Cache Pool Step 1

2. Enter an **SSD Cache Pool Name** for the pool. Maximum length of the pool name is 16 characters. Valid characters are [A~Z | a~z | 0~9 | -_<>].
3. Select the **Cache Type** as Read Cache (NRAID+).
4. Select an **I/O Type** from the drop-down list according to your application.
5. Please select SSDs for SSD cache pool. Maximum quantity of disk is 8. Select an **Enclosure** from the drop-down list to select SSDs from expansion enclosures.
6. Click the **Next** button to continue.

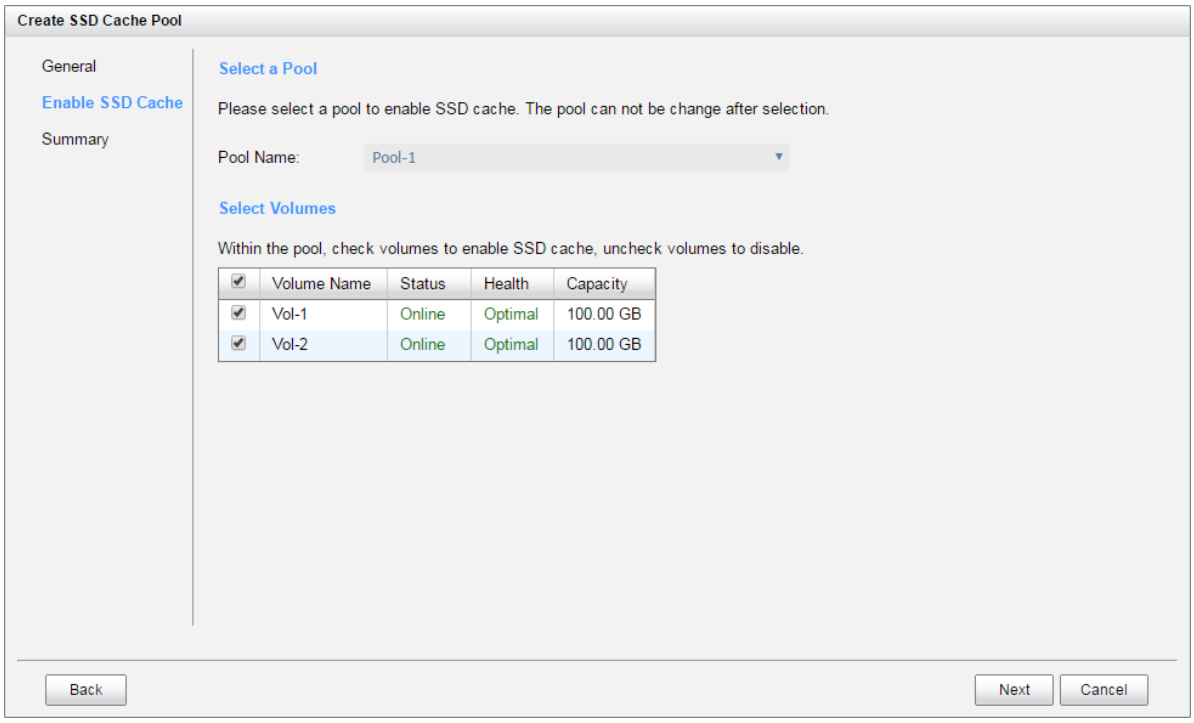

Figure 13 Create an SSD Cache Pool Step 2

7. Select a **Pool Name** from the drop-down list which lists available pools to be assigned to.
8. Within the pool, check **Volumes** to enable SSD cache, uncheck **Volumes** to disable.
9. Click the **Next** button to continue.

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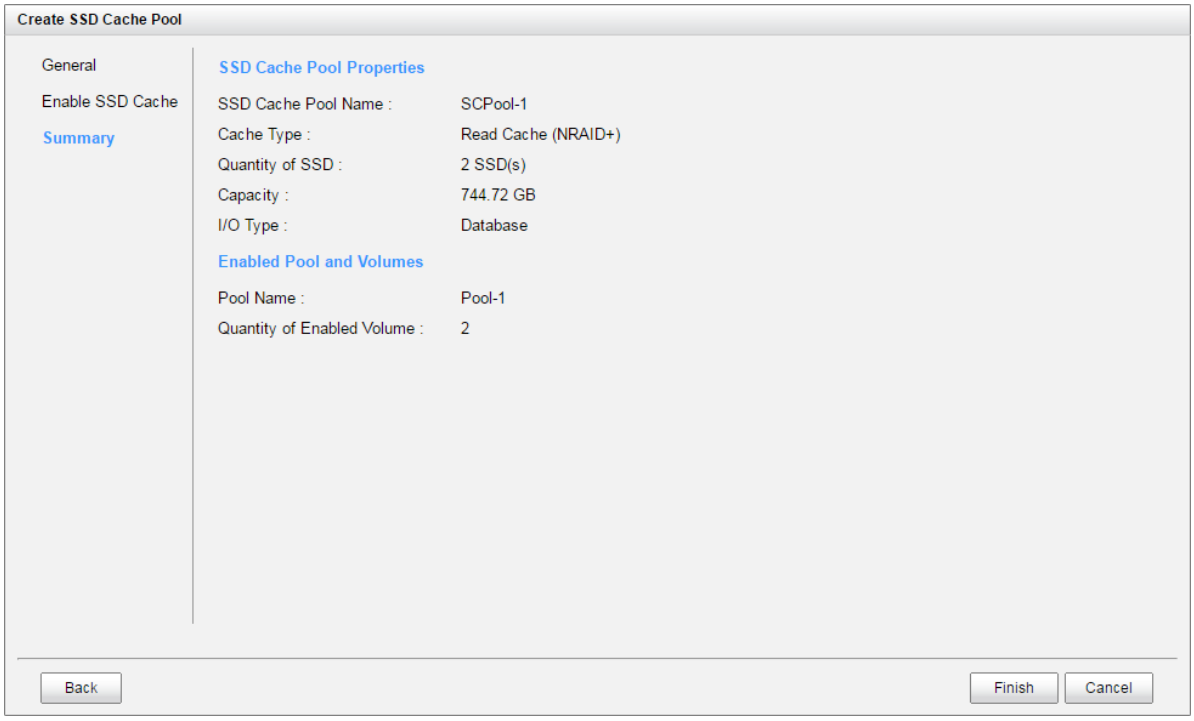

Figure 14 Create an SSD Cache Pool Step 3

10. After confirmation at summary page, click the **Finish** button to create a pool.

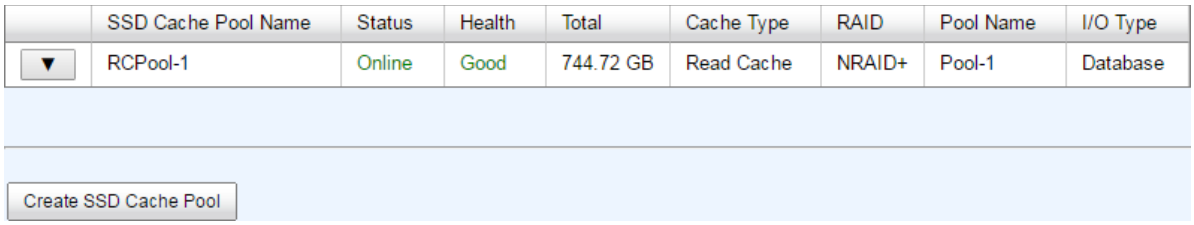

Figure 15 An SSD Cache Pool is Created

11. An SSD cache pool has been created.
12. Follow the step 1 to 11 to create another SSD cache pool with Read-write Cache (NRAID 1+) and set the I/O type as File System.

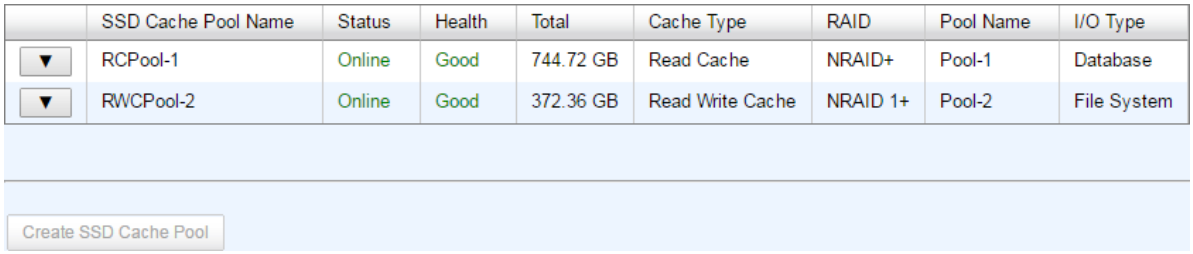

Figure 16 Another SSD Cache Pool is Created

TIP:
The **Create SSD Cache Pool** button will be grayed out when meet the following conditions.

- There are no available SSDs to create an SSD cache pool.
- There are no available pools which can be assigned to the SSD cache pool including the status of the pool is Migrating, Moving, Offline or the health of the pool is Failed.

List SSD Cache Pools

Select one of the SSD cache pools, it will display the related SSDs and enabled volumes. The pool properties can be configured by clicking the functions button ▼ to the left side of the specific pool.

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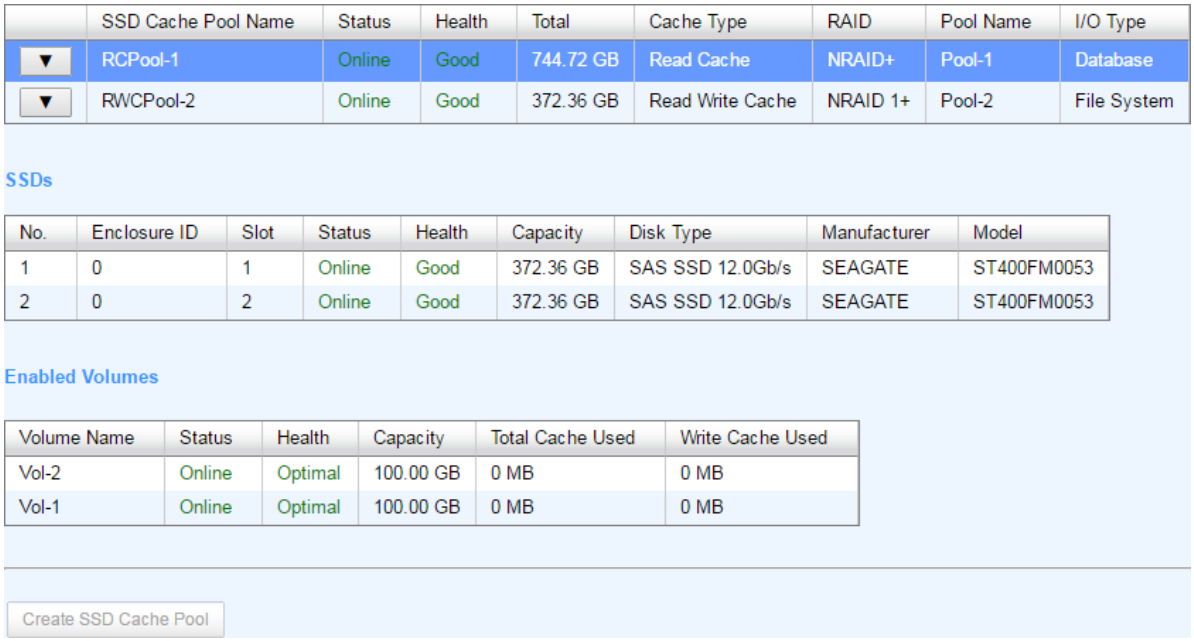

	SSD Cache Pool Name	Status	Health	Total	Cache Type	RAID	Pool Name	I/O Type
▼	RCPool-1	Online	Good	744.72 GB	Read Cache	NRAID+	Pool-1	Database
▼	RWCPool-2	Online	Good	372.36 GB	Read Write Cache	NRAID 1+	Pool-2	File System

SSDs

No.	Enclosure ID	Slot	Status	Health	Capacity	Disk Type	Manufacturer	Model
1	0	1	Online	Good	372.36 GB	SAS SSD 12.0Gb/s	SEAGATE	ST400FM0053
2	0	2	Online	Good	372.36 GB	SAS SSD 12.0Gb/s	SEAGATE	ST400FM0053

Enabled Volumes

Volume Name	Status	Health	Capacity	Total Cache Used	Write Cache Used
Vol-2	Online	Optimal	100.00 GB	0 MB	0 MB
Vol-1	Online	Optimal	100.00 GB	0 MB	0 MB

Create SSD Cache Pool

Figure 17 List SSD Cache Pools

This table shows the column descriptions.

Table 5 SSD Cache Pool Column Descriptions

Column Name	Description
SSD Cache Pool Name	The SSD cache pool name.
Status	The status of the pool: • Online: The SSD cache pool is online. • Offline: The SSD cache pool is offline. • Rebuilding: The SSD cache pool is being rebuilt. • Flushing: The SSD cache pool is being flushed.
Health	The health of the pool: • Good: The SSD cache pool is good. • Failed: The SSD cache pool is failed. • Degraded: The SSD cache pool is not healthy and not complete. The reason could be missing or failed SSDs.
Total	Total capacity of the SSD cache pool.
Cache Type	The SSD cache type: • Disabled. • Enabled.
RAID	The RAID level of the SSD cache pool:

	• NRAID+: SSD read cache. • NRAID 1+: SSD read-write cache.
Pool Name	Which pool the SSD cache pool assigns to.
I/O Type	The I/O type of the SSD cache pool: • Database. • File System. • Web Service. • Customization.

Table 6 SSDs Column Descriptions

Column Name	Description
No.	The number of the SSD or SSD group: • SSD Read Cache: The number of the SSD. • SSD Read-write Cache: The number of the SSD group.
Enclosure ID	The enclosure ID.
Slot	The position of the SSD.
Status	The status of the SSD: • Online: The SSD is online. • Missing: The SSD is missing in the pool. • Rebuilding: The SSD is being rebuilt. • Flushing: The SSD is being flushed.
Health	The health of the SSD: • Good: The disk drive is good. • Failed: The disk drive is failed. • Error Alert: S.M.A.R.T. error alerts. • Read Errors: The SSD has unrecoverable read errors.
Capacity	The capacity of the SSD.
Disk Type	The type of disk drive: • [SAS SSD | SATA SSD] • [12.0Gb/s | 6.0Gb/s | 3.0Gb/s | 1.5Gb/s]
Manufacturer	The manufacturer of the SSD.
Model	The model name of SSD.

Table 7 Enabled Volume Column Descriptions

Column Name	Description
Volume Name	The volume is enabled SSD cache.
Status	The status of the volume:

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	• Online: The volume is online. • Offline: The volume is offline. • Rebuilding: The volume is being rebuilt. • Flushing: The volume is being flushed.
Health	The health of the volume: • Optimal: the volume is working well and there is no failed disk in the RG. • Failed: the pool disk of the volume has single or multiple failed disks than its RAID level can recover from data loss. • Degraded: At least one disk from the pool of the volume is failed or plugged out. • Partially optimal: the volume has experienced recoverable read errors. After passing parity check, the health will become Optimal.
Capacity	The capacity of the volume.
Total Cache Used	The capacity of total cache used.
Write Cache Used	The capacity of write cache used.

Operations on SSD Cache Pools

The options available in this tab:

Add or Remove SSDs

For an SSD read cache, click ▼ **-> Add / Remove SSDs** to add into or remove SSDs from the SSD cache pool. Check SSDs to add into the SSD cache pool, and uncheck SSDs to remove from the SSD cache pool.

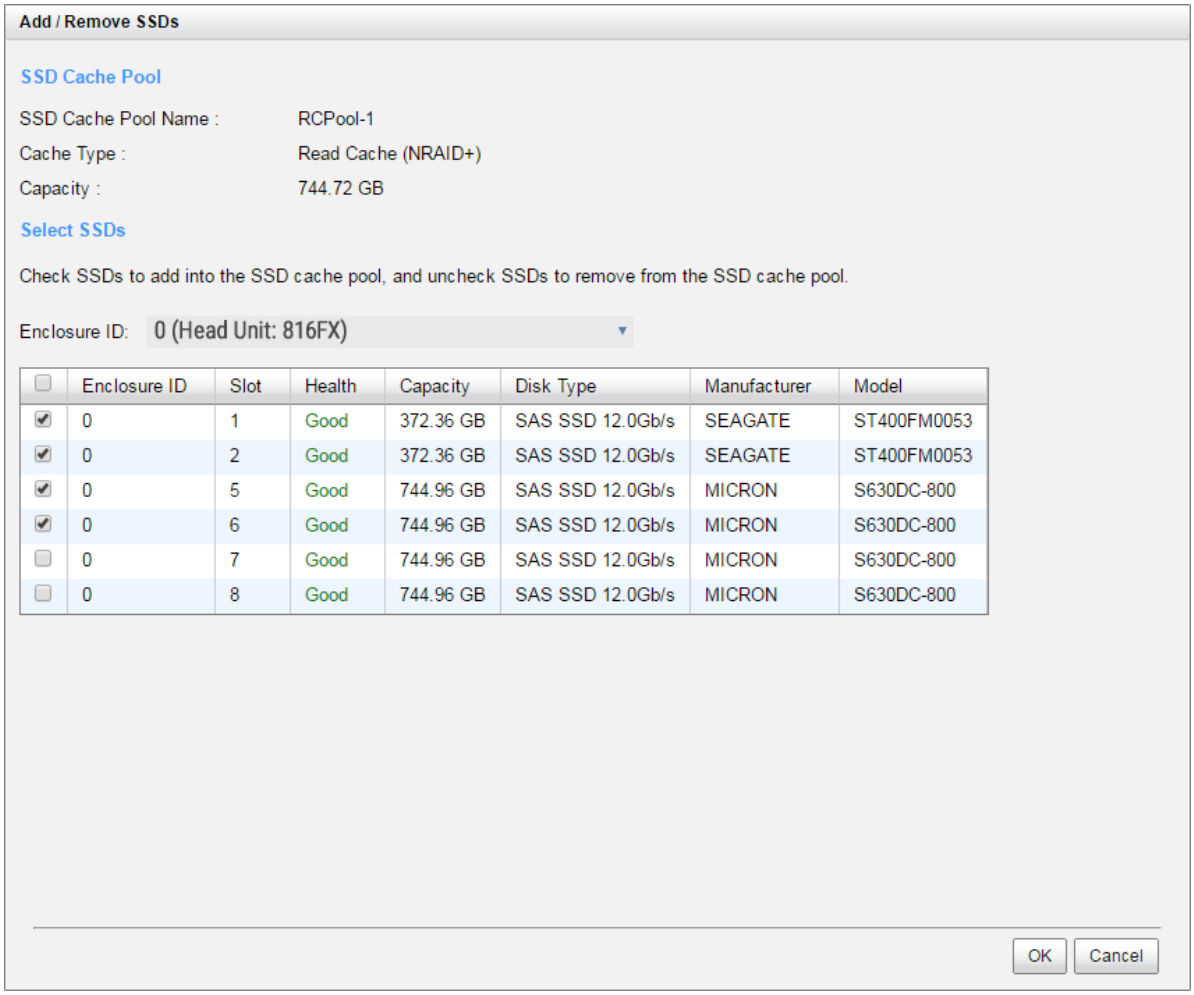

Figure 18 Add / Remove SSDs from the SSD Cache Pool

For an SSD read-write cache, click ▼ **-> Add SSDs** to add SSDs into the SSD cache pool. Please select two SSDs at a time to add into the SSD cache pool.

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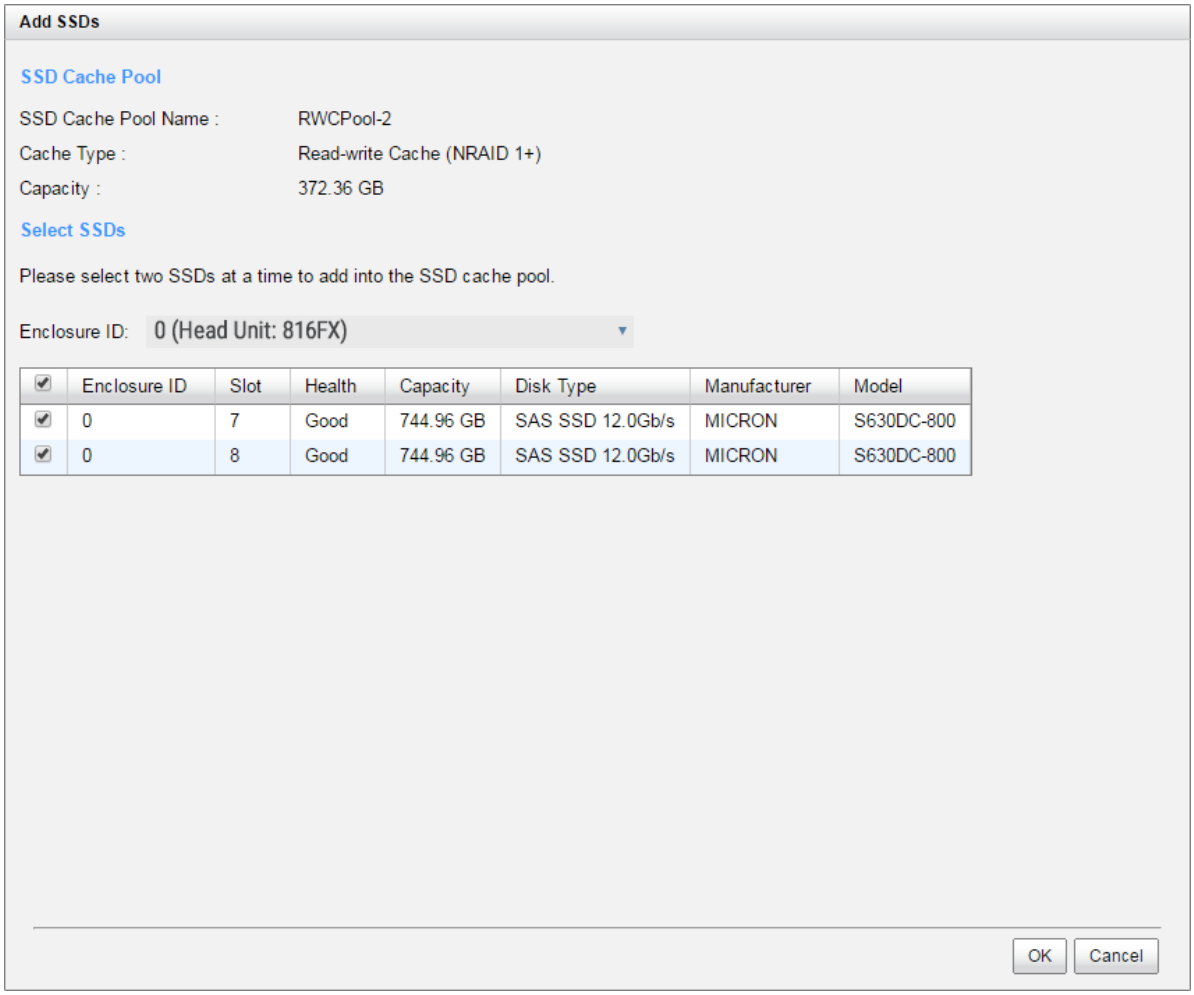

Figure 19 Add SSDs into the SSD Cache Pool

Delete an SSD Cache Pool

Click ▼ **-> Delete** to delete the SSD cache pool. If deleting an SSD read-write cache pool, it will take times to flush data from SSDs to HDDs. The SSD cache pool will be deleted after flushed, otherwise the data may be corrupt.

More Information of the SSD Cache Pool

Click ▼ **-> More Information** to show the detail information of the SSD cache pool.

Monitor SSD Cache Statistics

This section will describe the monitoring of SSD cache statistics.

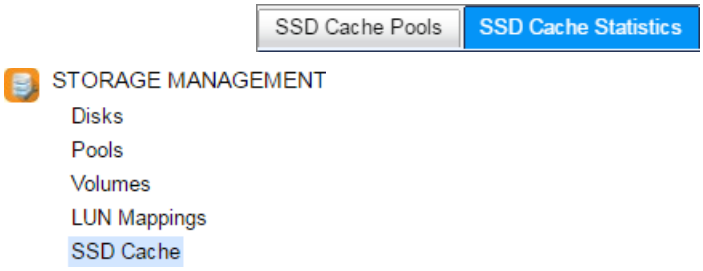

Figure 20 SSD Cache Function Submenu

Select the **SSD Cache Statistics** function tab in the **SSD Cache** function submenu to monitor the SSD cache statistics. Here is an example of monitoring the volume of the SSD read-write cache pool.

1. Select an **SSD Cache Pool Name** and select an **Enabled Volumes** which you want to monitor.

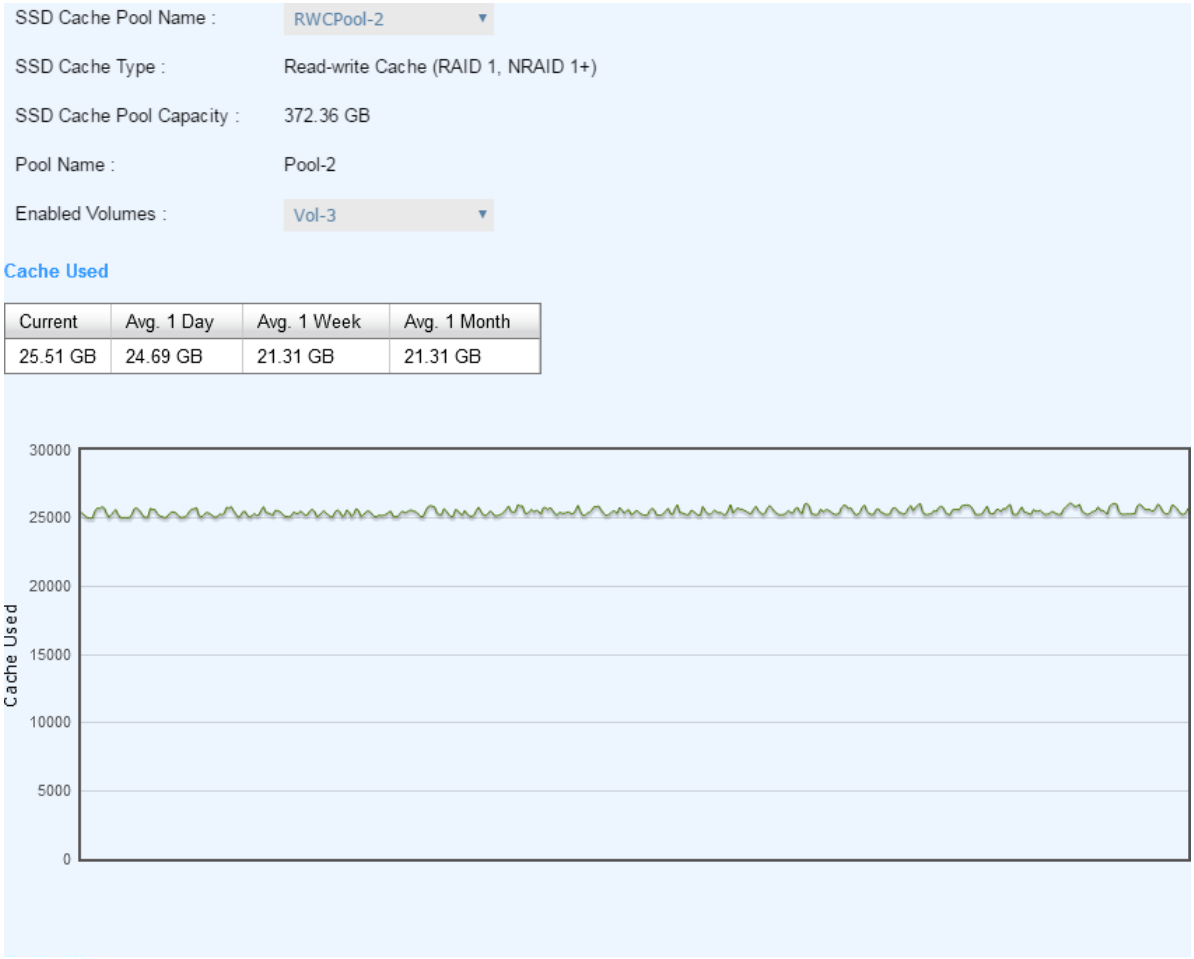

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Figure 21 SSD Cache Statistics

2. The SSD cache statistics include **Cache Used**, **Cache Hits**, and **Cache Hit Ratio**. Each items have current value, average 1 day value, average 1 week value, and average 1 month value. The diagram displays the current value with 30 seconds refresh and total 4 hours.

Table 8 SSD Cache Statistics Descriptions

Column Name	Description
Cache Used	How much capacity of the SSD cache pool is used by the volume? Unit is MB, GB, or TB.
Cache Hits	How many cache hits occurred by the volume? Unit is the number of times
Cache Hit Ratio	How many cache hit ratio occurred by the volume? Unit is percentage.

Test Results

Test Cases 1: SSD Read Cache with 1 / 2 / 4 / 8 SSDs

This test verifies the dramatic performance gains offered by SSD read cache. We test the SSD read cache with 1 / 2 / 4 / 8 SSDs. According to the design structure of RAID level in SSD read cache pool, in theory, the more SSDs are used, the better SSD read cache is. We also set the populate-on-read threshold to 1 which means the data hits once and is populated to SSD.

Test Equipment and Configurations

- Server
  - Model: HP Z840 (CPU: 2 x Xeon E5-2620v3 2.4Hz / RAM: 32GB)
    FC HBA: QLogic QLE2694-SR
    OS: Windows Server 2012 R2
  - Model: Dell E25S (CPU: 2 x Xeon E5-2620v3 2.4Hz / RAM:32GB)
    FC HBA: QLogic QLE2694-SR
    OS: Windows Server 2012 R2
- Storage
  - Model: JetStor 824FXD
    Memory: 16GB (2 x 8GB in bank 1 & 3) per controller
    Firmware 1.1.2
    HDD: 16 x Seagate Constellation ES, ST500NM0001, 500GB, SAS 6Gb/s
    SSD: 1 / 2 / 4 / 8 x HGST Ultrastar SSD800MH.B, HUSMH8010BSS200, 100GB, SAS 12Gb/s
  - HDD Pool: 1 x RAID 5 Pool with 16 x NL-SAS HDDs in Controller 1
  - HDD Volume: 2 x 45GB in Pool
  - FC Session: 2 per Volume
- SSD Cache
  - **SSD Cache Pool: Read Cache (NRAID+) with 1 / 2 / 4 / 8 x SAS SSDs**
  - I/O Type: Customization
    Cache Block Size: 4MB
    Populate-on-read Threshold: 1
    Populate-on-write Threshold: 0

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- I/O Pattern
  - Tool: IOmeter V1.1.0
  - Workers: 1
  - Outstanding (Queue Depth): 128
  - **Access Specifications: 4KB, 100% Read, 100% Random**
- Test Scenario
  - HP server runs 1 x Volume (45GB) of RAID 5 Pool in Controller 1 via 2 x FC ports with MPIO
  - Dell server runs 1 x Volume (45GB) of RAID 5 Pool in Controller 1 via 2 x FC ports with MPIO

Test Diagram

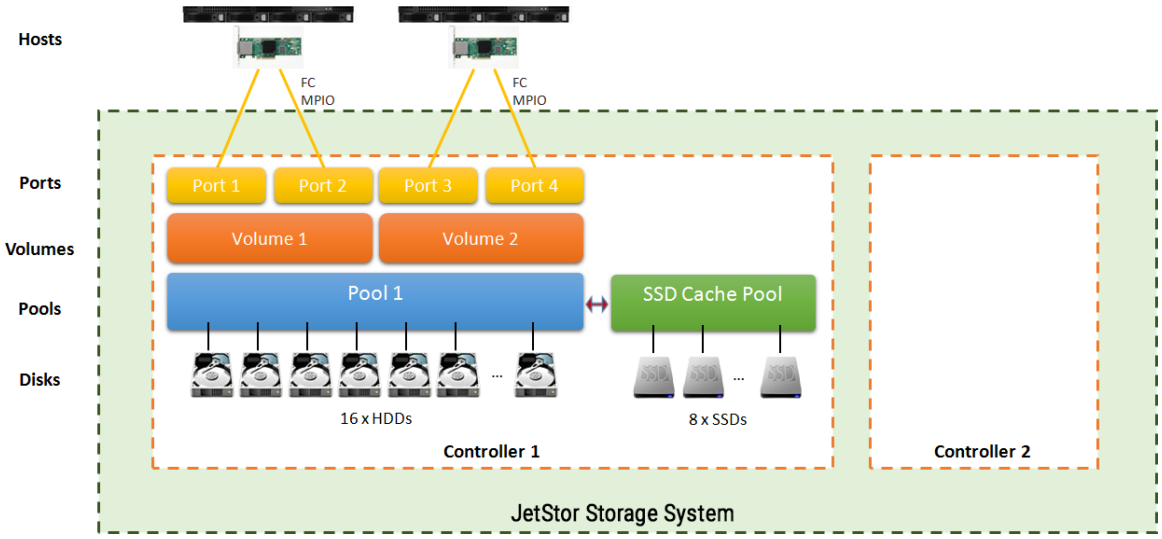

Figure 22 SSD Cache Test Diagram

Test Result

Table 9 The Test Result of SSD Read Cache with 1 / 2 / 4 / 8 SSDs

Volume Capacity	Disable SSD Cache (IOPS)	Enable SSD Cache				Improved
		No. of SSDs	SSD Capacity	Warm up Time	After Populating (IOPS)	
90GB	4,512	1	100GB	7.5 min.	121,326	2,589%
90GB	4,512	2	200GB	7 min.	192,374	4,164%

90GB	4,512	4	400GB	7 min.	214,986	4,665%
90GB	4,512	8	800GB	7 min.	216,434	4,697%

Without SSD cache, the average of IOPS is 4,512. Enable SSD cache with 8 SSDs, IOPS increases to 216,434. It improves (216,434 – 4,512) / 4,512 = 46.968 == 4,697%. And the warm-up time is about 7 minutes.

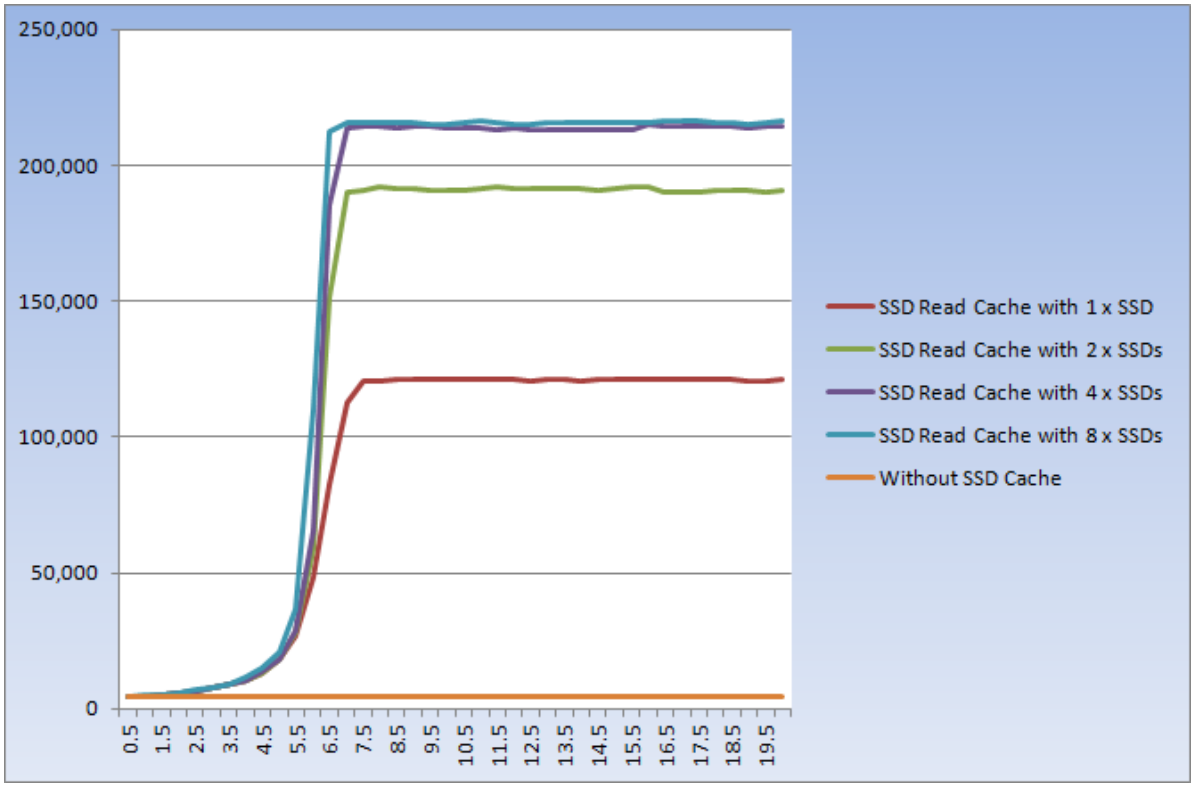

Figure 23 The Chart of SSD Read Cache with 1 / 2 / 4 / 8 SSDs

According to the chart for the relationship between IOPS and warm-up time, the orange line is the IOPS without SSD cache. And the others are enabled SSD cache. At the period of 1 to 7 minutes, the data is hit and read from the SSDs. If it is not hit, the data is read from HDD and populated to the SSDs. After 7 minutes, the IOPS climbs to the top and stay stable. This means that the data are all in the SSDs.

Summary

- SSD Cache 2.0 can improve random read performance by up to 47 times.
- The more SSDs are used, the better SSD read cache is.

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TIP:
You can also watch the **SSD Cache -> SSD Cache Statistics** page in Web UI to monitor the SSD cache changes, or **Performance -> Disks** by enabling the HDD and SSD slots to monitor the HDD and SSD I/O changes.

Test Cases 2: SSD Write Cache with 2 / 4 / 8 SSDs

We plan to test the SSD read-write cache with 2 / 4 / 8 SSDs in this test. The same, we set the populate-on-write threshold to 1 which means the data hits once and is populated to SSD.

Test Equipment and Configurations

- Server
  - Model: HP Z840 (CPU: 2 x Xeon E5-2620v3 2.4Hz / RAM: 32GB)
    FC HBA: QLogic QLE2694-SR
    OS: Windows Server 2012 R2
  - Model: Dell E25S (CPU: 2 x Xeon E5-2620v3 2.4Hz / RAM:32GB)
    FC HBA: QLogic QLE2694-SR
    OS: Windows Server 2012 R2
- Storage
  - Model: JetStor 824FXD
    Memory: 16GB (2 x 8GB in bank 1 & 3) per controller
    Firmware 1.1.2
    HDD: 16 x Seagate Constellation ES, ST500NM0001, 500GB, SAS 6Gb/s
    SSD: 2 / 4 / 8 x HGST Ultrastar SSD800MH.B, HUSMH8010BSS200, 100GB, SAS 12Gb/s
  - HDD Pool: 1 x RAID 5 Pool with 16 x NL-SAS HDDs in Controller 1
  - HDD Volume: 2 x 30GB in Pool
  - FC Session: 2 per Volume
- SSD Cache
  - **SSD Cache Pool: Read-write Cache (NRAID 1+) with 2 / 4 / 8 x SAS SSDs**
  - I/O Type: Customization
    Cache Block Size: 4MB

Populate-on-read Threshold: 1
Populate-on-write Threshold: 1

- I/O Pattern
  - Tool: IOmeter V1.1.0
  - Workers: 1
  - Outstanding (Queue Depth): 128
  - **Access Specifications: 4KB, 100% Write, 100% Random**
- Test Scenario
  - HP server runs 1 x Volume (30GB) of RAID 5 Pool in Controller 1 via 2 x FC ports with MPIO
  - Dell server runs 1 x Volume (30GB) of RAID 5 Pool in Controller 1 via 2 x FC ports with MPIO

Test Result

Table 10 The Test Result of SSD Read-write Cache with 2 / 4 / 8 SSDs

Volume Capacity	Disable SSD Cache (IOPS)	Enable SSD Cache				Improved
		No. of SSDs	SSD Capacity	Warm up Time	After Populating (IOPS)	
60GB	1,660	2	100GB	13 min.	41,358	2,391%
60GB	1,660	4	200GB	9 min.	84,405	4,985%
60GB	1,660	8	400GB	6.5 min.	143,898	8,569%

Without SSD cache, the average of IOPS is 1,660. Enable SSD cache with 8 SSDs, IOPS increases to 143,898. It improves (143,898 – 1,660) / 1,660 = 85.685 == 8,569%. And the warm-up time is about 6.5 minutes.

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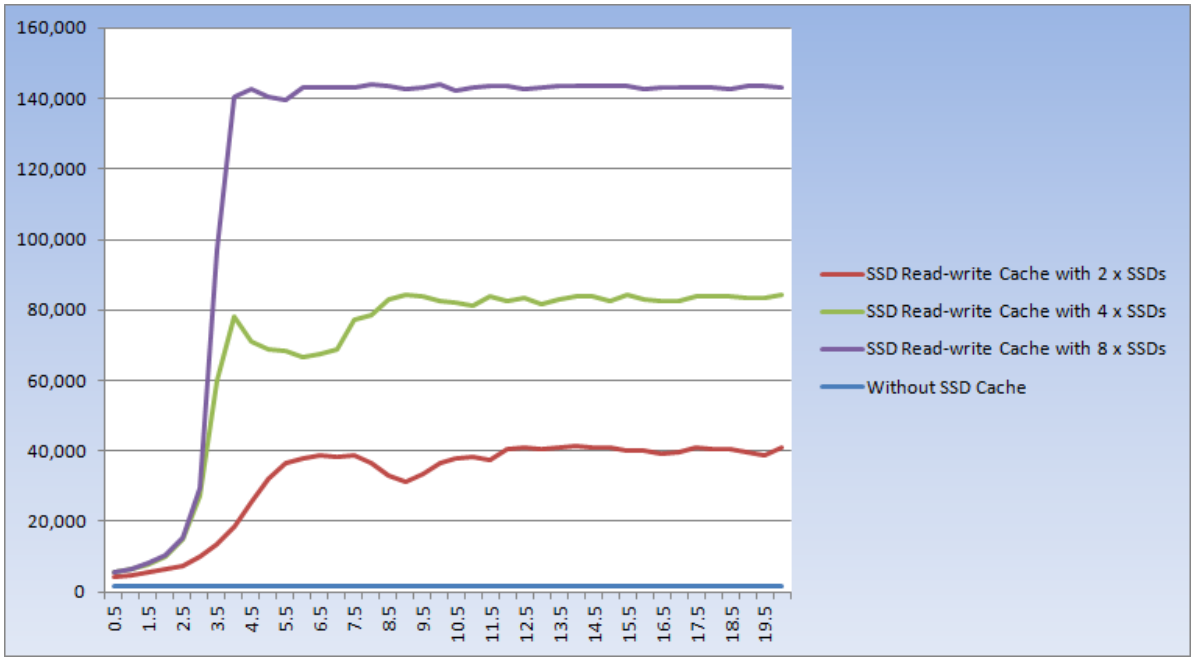

Figure 24 The Chart of SSD Read-write Cache with 2 / 4 / 8SSDs

Summary

- SSD Cache 2.0 can improve random write performance by up to 86 times.
- The more SSDs are used, the better SSD write cache is.

Test Cases 3: Simulate Database Application

This test simulates the database application. We use the Database I/O type in the configuration of SSD cache pool, and use the database access pattern (8KB, 67% read, 100% random) to test.

Test Equipment and Configurations

- Server
  - Model: HP Z840 (CPU: 2 x Xeon E5-2620v3 2.4Hz / RAM: 32GB)
    FC HBA: QLogic QLE2694-SR
    OS: Windows Server 2012 R2
  - Model: Dell E25S (CPU: 2 x Xeon E5-2620v3 2.4Hz / RAM:32GB)
    FC HBA: QLogic QLE2694-SR
    OS: Windows Server 2012 R2
- Storage

- Model: JetStor 824FXD
  Memory: 16GB (2 x 8GB in bank 1 & 3) per controller
  Firmware 1.1.2
  HDD: 16 x Seagate Constellation ES, ST500NM0001, 500GB, SAS 6Gb/s
  SSD: 2 x HGST Ultrastar SSD800MH.B, HUSMH8010BSS200, 100GB, SAS 12Gb/s
- HDD Pool: 1 x RAID 5 Pool with 16 x NL-SAS HDDs in Controller 1
- **HDD Volume: 2 x 30GB / 2 x 45GB / 2 x 60GB / 2 x 90GB in Pool**
- FC Session: 2 per Volume

- SSD Cache
  - **SSD Cache Pool: Read-write Cache (NRAID 1+) with 2 x SAS SSDs**
  - **I/O Type: Database**
    Cache Block Size: 1MB
    Populate-on-read Threshold: 2
    Populate-on-write Threshold: 1
- I/O Pattern
  - Tool: IOmeter V1.1.0
  - Workers: 1
  - Outstanding (Queue Depth): 128
  - **Access Specifications: 8KB, 67% Read, 100% Random** (Database Access Pattern)
- Test Scenario
  - HP server runs 1 x Volume (30GB / 45GB / 60GB / 90GB) of RAID 5 Pool in Controller 1 via 2 x FC ports with MPIO
  - Dell server runs 1 x Volume (30GB / 45GB / 60GB / 90GB) of RAID 5 Pool in Controller 1 via 2 x FC ports with MPIO

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Test Result

Table 11 Test Result of Database Application

Volume Capacity	Disable SSD Cache (IOPS)	Enable SSD Cache				Improved
		No. of SSDs	SSD Capacity	Warm up Time	After Populating (IOPS)	
60GB	2,799	2	100GB	19 min.	64,809	2,215%
90GB	2,799	2	100GB	23 min.	63,660	2,174%
120GB	2,799	2	100GB	N/A min.	3,999	43%

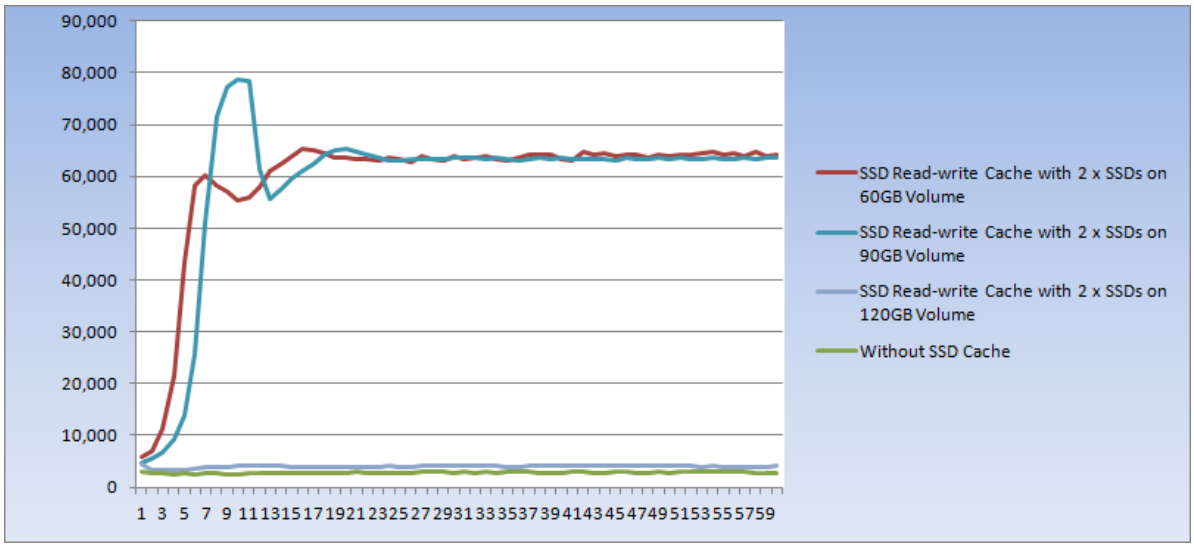

Figure 25 The Chart of Database Application on 60GB / 90GB / 120GB / 180GB Volumes

The same, the result is very good when the amount of the hot data is less than the capacity of SSD cache pool.

Summary

- User has to accurately estimate the amount of hot data used to achieve the best result.

Test Cases 4: Best Practice of SSD Read Cache

The cases above are tested on single controller. The following test provides the best practice of SSD read cache on dual controller. We assume that the performance can be twice than the test on single controller.

Test Equipment and Configurations

- Server
  - Model: HP Z840 (CPU: 2 x Xeon E5-2620v3 2.4Hz / RAM: 32GB)
    FC HBA: QLogic QLE2694-SR
    OS: Windows Server 2012 R2
  - Model: Dell E25S (CPU: 2 x Xeon E5-2620v3 2.4Hz / RAM:32GB)
    FC HBA: QLogic QLE2694-SR
    OS: Windows Server 2012 R2
- Storage
  - Model: JetStor 824FXD
    Memory: 16GB (2 x 8GB in bank 1 & 3) per controller
    Firmware 1.1.2
    HDD: 16 x Seagate Constellation ES, ST500NM0001, 500GB, SAS 6Gb/s
    SSD: 8 x HGST Ultrastar SSD800MH.B, HUSMH8010BSS200, 100GB, SAS 12Gb/s
  - HDD Pool: 1 x RAID 5 Pool 1 with 8 x NL-SAS HDDs in Controller 1
    1 x RAID 5 Pool 2 with 8 x NL-SAS HDDs in Controller 2
  - HDD Volume: 2 x 45GB in Pool 1
    2 x 45GB in Pool 2
  - FC Session: 2 per Volume
- SSD Cache
  - **SSD Cache Pool: Read Cache (NRAID+) with 8 x SAS SSDs**
  - I/O Type: Customization
    Cache Block Size: 4MB
    Populate-on-read Threshold: 1
    Populate-on-write Threshold: 0
- I/O Pattern
  - Tool: IOmeter V1.1.0
  - Workers: 1
  - Outstanding (Queue Depth): 128
  - **Access Specifications: 4KB, 100% Read, 100% Random**
- Test Scenario
  - HP server runs 1 x Volume (45GB) of RAID 5 Pool1 in Controller 1 via 2 x FC ports with MPIO

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- Dell server runs 1 x Volume (45GB) of RAID 5 Pool2 in Controller 2 via 2 x FC ports with MPIO

Test Diagram

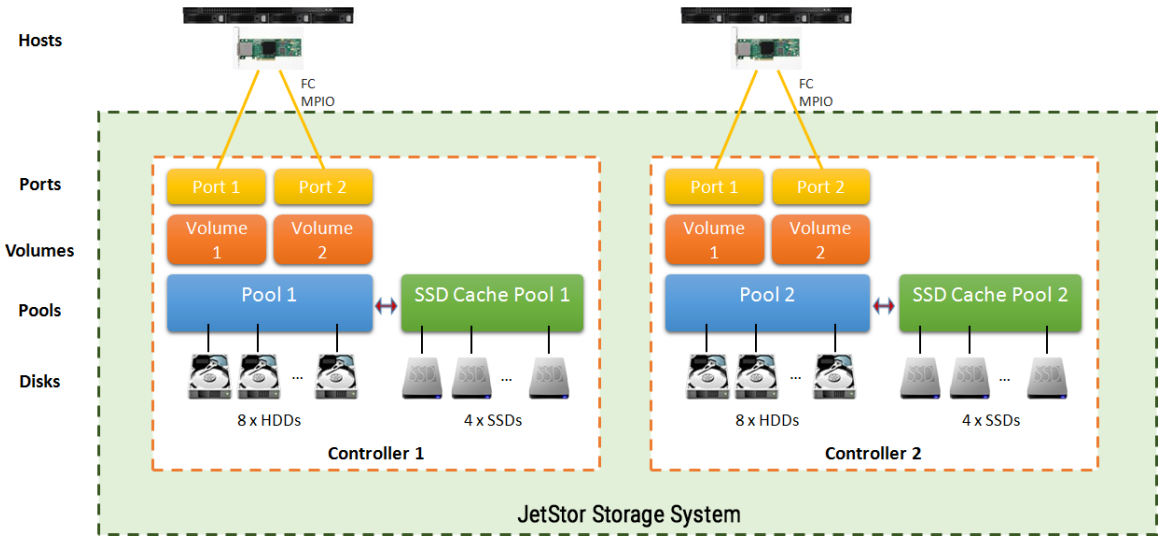

Figure 26 SSD Cache Test Diagram

Test Result

Table 12 The Test Result of SSD Read Cache with 1 / 2 / 4 / 8 SSDs

Volume Capacity	Disable SSD Cache (IOPS)	Enable SSD Cache				Improved
		No. of SSDs	SSD Capacity	Warm up Time	After Populating (IOPS)	
2 x 90GB = 180GB	4,986	2 x 4 = 8	2 x 400GB = 800GB	13.5 min.	461,037	9,147%

Without SSD cache, the average of IOPS is 4,986. After enabling SSD cache with 8 SSDs, IOPS increases to 461,037. It improves (461,037 –4,986) / 4,986 = 91.466 == 9,147%. And the warm-up time is about 13.5 minutes.

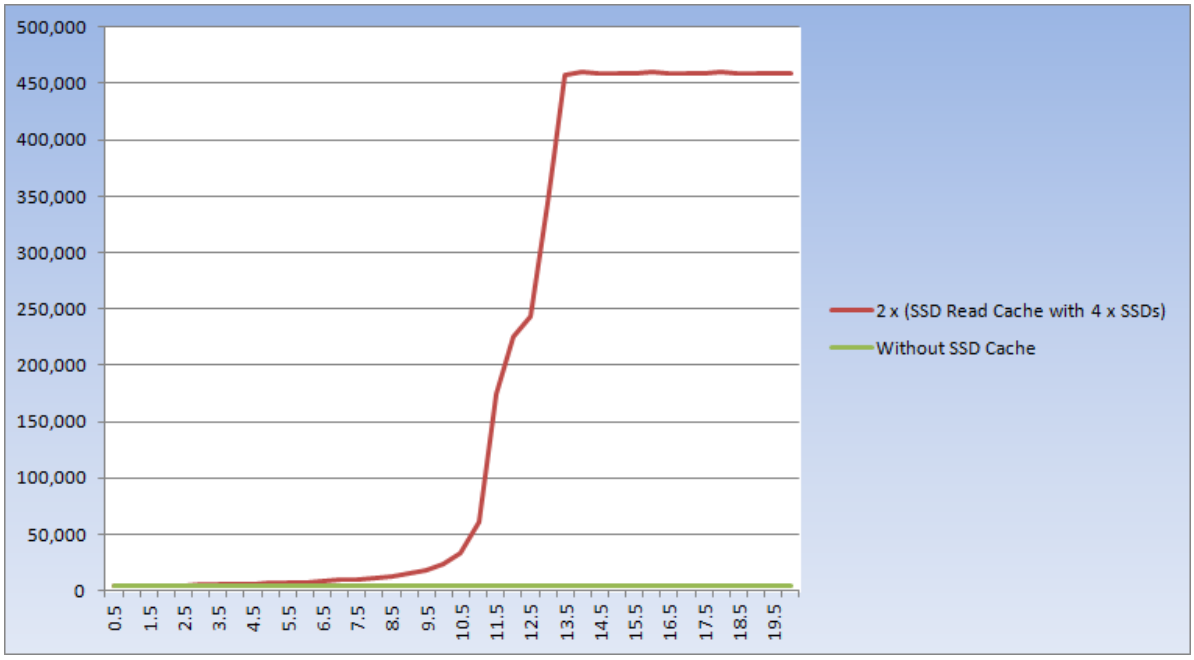

Figure 27 The Chart of the Best Practice of SSD Read Cache

Summary

- SSD Cache 2.0 can improve random read performance by up to 92 times.
- The test is the highest SSD cache performance of a system.

Test Cases 5: Best Practice of SSD Write Cache

This test provides the best practice of SSD write cache on dual controller. The same, we assume that the performance can be twice than the test on single controller.

Test Equipment and Configurations

- Server
  - Model: HP Z840 (CPU: 2 x Xeon E5-2620v3 2.4Hz / RAM: 32GB)
    FC HBA: QLogic QLE2694-SR
    OS: Windows Server 2012 R2
  - Model: Dell E25S (CPU: 2 x Xeon E5-2620v3 2.4Hz / RAM:32GB)
    FC HBA: QLogic QLE2694-SR
    OS: Windows Server 2012 R2
- Storage

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- Model: JetStor 824FXD
  Memory: 16GB (2 x 8GB in bank 1 & 3) per controller
  Firmware 1.1.2
  HDD: 16 x Seagate Constellation ES, ST500NM0001, 500GB, SAS 6Gb/s
  SSD: 8 x HGST Ultrastar SSD800MH.B, HUSMH8010BSS200, 100GB, SAS 12Gb/s
- HDD Pool: 1 x RAID 5 Pool 1 with 8 x NL-SAS HDDs in Controller 1
  1 x RAID 5 Pool 2 with 8 x NL-SAS HDDs in Controller 2
- HDD Volume: 2 x 45GB in Pool 1
  2 x 45GB in Pool 2
- FC Session: 2 per Volume

- SSD Cache
  - **SSD Cache Pool: Read Cache (NRAID+) with 8 x SAS SSDs**
  - I/O Type: Customization
    Cache Block Size: 4MB
    Populate-on-read Threshold: 1
    Populate-on-write Threshold: 1
- I/O Pattern
  - Tool: IOmeter V1.1.0
  - Workers: 1
  - Outstanding (Queue Depth): 128
  - **Access Specifications: 4KB, 100% Write, 100% Random**
- Test Scenario
  - HP server runs 1 x Volume (45GB) of RAID 5 Pool1 in Controller 1 via 2 x FC ports with MPIO
  - Dell server runs 1 x Volume (45GB) of RAID 5 Pool2 in Controller 2 via 2 x FC ports with MPIO

Test Result

Table 13 The Test Result of SSD Read Cache with 1 / 2 / 4 / 8 SSDs

Volume Capacity	Disable SSD Cache (IOPS)	Enable SSD Cache				Improved
		No. of SSDs	SSD Capacity	Warm up Time	After Populating (IOPS)	
2 x 90GB = 180GB	1,268	2 x 4 = 8	2 x 200GB = 400GB	18 min.	217,495	17,053%

Without SSD cache, the average of IOPS is 1,267. After enabling SSD cache with 8 SSDs, IOPS increases to 217,495. It improves (217,495 –1,268) / 1,268 = 170.526 == 17,053%. And the warm-up time is about 18 minutes.

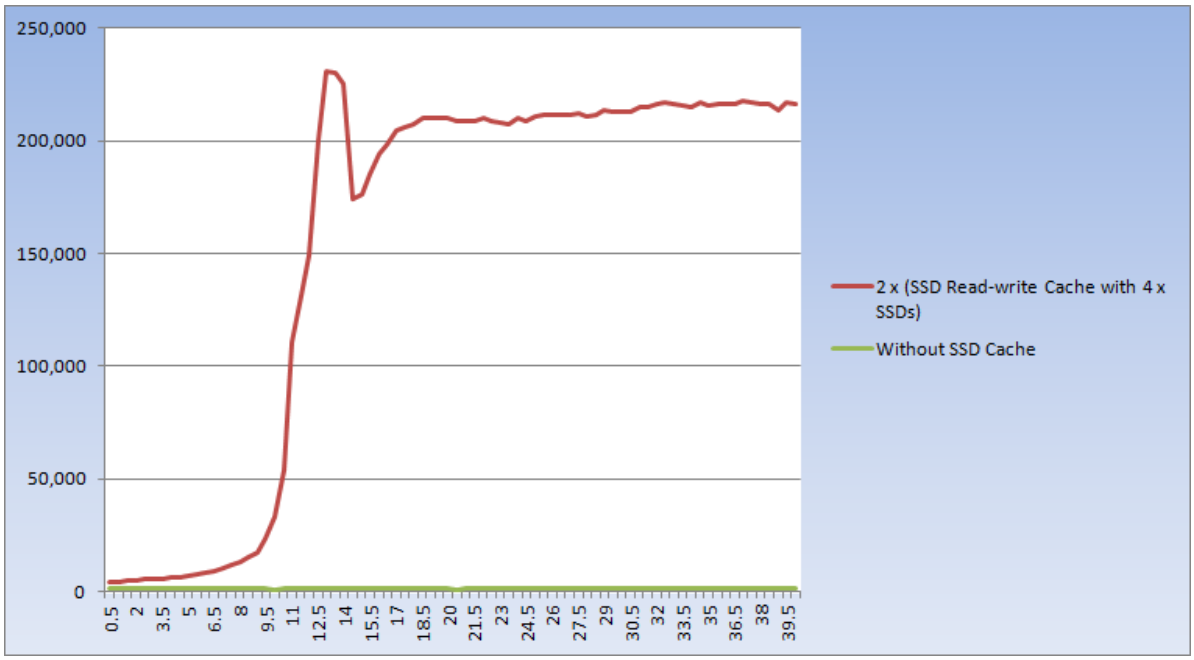

Figure 28 The Chart of the Best Practice of SSD Write Cache

Summary

- SSD Cache 2.0 can improve random read performance by up to 171 times.
- The test is the highest increasing rate of SSD cache in a system.

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Conclusion

The hybrid storage concept of storage acceleration uses the idea of hot data to accelerate I/O performance of an entire storage system. When hardware and IT administration costs are taken into consideration, it turns out that SSD cache as available in modern SAN systems is generally the best way for most businesses to gain the benefits of the faster performance from flash based storage without sacrificing the reliability of their data.

Apply To

- JetStor X Series FW 1.1.2 and later

Reference

Obsolete JetStor White Paper

- SSD_Caching.v1.5

Appendix

Related Documents

There are related documents which can be downloaded from the website.

- All JetStor X Series Documents
- JetStor X Series Hardware Manual
- JetStor X Series Software Manual
- White Papers
- Application Notes

Technical Support

Do you have any questions or need help trouble-shooting a problem? Please contact JetStor Support, we will reply to you as soon as possible.

- Via the Web: https://acnc.com/support
- Via Telephone: 800.213.2667
- Via Skype Chat, Skype ID: jetstor.support
- Via Email: support@acnc.com

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