XCubeSANSeries White Paper

RAIDEE Technology

QSAN Technology, Inc.
www.QSAN.com

QSAN

October 2019

This edition applies to QSAN XCubeSAN series. QSAN believes the information in this publication is accurate as of its publication date. The information is subject to change without notice.

Notices

This XCubeSANseries white paper is applicable to the following XCubeSAN models:

XCubeSAN Storage System4U 2:Ufi!Sbdl!Npvou Models

Model Name	Controller Type	Form Factor, Bay Count, and Rack Unit
XS5224D	Dual Controller	LFF 24-disk 4U Chassis
XS3224D	Dual Controller	LFF 24-disk 4U Chassis
XS3224S	Single Controller	LFF 24-disk 4U Chassis
XS1224D	Dual Controller	LFF 24-disk 4U Chassis
XS1224S	Single Controller	LFF 24-disk 4U Chassis

XCubeSAN Storage System3U 19Ufi Rack Mount Models

Model Name	Controller Type	Form Factor, Bay Count, and Rack Unit
XS5216D	Dual Controller	LFF 16-disk 3U Chassis
XS3216D	Dual Controller	LFF 16-disk 3U Chassis
XS3216S	Single Controller	LFF 16-disk 3U Chassis
XS1216D	Dual Controller	LFF 16-disk 3U Chassis
XS1216S	Single Controller	LFF 16-disk 3U Chassis

XCubeSAN Storage System 2U19Ufi Rack Mount Models

Model Name	Controller Type	Form Factor, Bay Count, and Rack Unit
XS5212D	Dual Controller	LFF 12-disk 2U Chassis
XS5212S	Single Controller	LFF 12-disk 2U Chassis
XS3212D	Dual Controller	LFF 12-disk 2U Chassis
XS3212S	Single Controller	LFF 12-disk 2U Chassis
XS1212D	Dual Controller	LFF 12-disk 2U Chassis
XS1212S	Single Controller	LFF 12-disk 2U Chassis
XS5226D	Dual Controller	SFF 26-disk 2U Chassis
XS5226S	Single Controller	SFF 26-disk 2U Chassis
XS3226D	Dual Controller	SFF 26-disk 2U Chassis
XS3226S	Single Controller	SFF 26-disk 2U Chassis
XS1226D	Dual Controller	SFF 26-disk 2U Chassis

XS1226S	Single Controller	SFF 26-disk 2U Chassis

Information contained in document has been reviewed for accuracy. But it could include typographical errors or technical inaccuracies. Changes are made to the document periodically. These changes will be incorporated in new editions of the publication. QSAN may make improvements or changes in the products. All features, functionality, and product specifications are subject to change without prior notice or obligation. All statements, information, and recommendations in this document do not constitute a warranty of any kind, express or implied.

Any performance data contained herein was determined in a controlled environment. Therefore, the results obtained in other operating environments may vary significantly. Some measurements may have been made on development-level systems and there is no guarantee that these measurements will be the same on generally available systems. Furthermore, some measurements may have been estimated through extrapolation. Actual results may vary. Users of this document should verify the applicable data for their specific environment.

This information contains examples of data and reports used in daily business operations. To illustrate them as completely as possible, the examples include the names of individuals, companies, brands, and products. All of these names are fictitious and any similarity to the names and addresses used by an actual business enterprise is entirely coincidental.

Table of Contents

RAID EE Technology

Executive Summary

The RAID architecturewhich has been in existence for over 30+ years now is undergoing a wave of transformation. The original RAID technology has failed to address the problem of excessive rebuilding time due to TB class large capacity hard disk drives. The new generation RAID technology based onthe traditional block technology, which we call RAID EE, is seen as a path to sdving the traditional RAID flaw.

INFORMATION:
RAIDEEtechnology is available in SANOS firmware 1.30 and the performance is greatly improved in SANOS firmware 1.4.1.

Audience

This document is applicable for QSAN customers and partners who are interested in learning about RAIDEEfor solving the problem of excessive rebuilding time. It assumes the reader is familiar with QSAN products and has general IT experience, includingknowledge as a system or network administrator. If there is any question, please refer to the user manuals of products, or contact QSANsupport for further assistance.

Overview

RAID (Redundant Array of Independent Disks) is to combine multiple independent physical disks based on a certain algorithm to form a virtual logical disk that provides a larger capacity, higher performance, or better data error tolerance. RAID has been the basic technology of storage system as a mature and reliable data protection standard. However, with the rapid growth in demand of disk drive for data storage and the advent of high-performance applications in recent years, traditional RAID has gradually revealed its defects.

As hard disk capacity increases, the amount of time required to rebuild RAID data has also dramatically increased. This makes one of the most troubl es for enterprise storage

management today. In the past days when the hard disk capacity was only 10GB to 100GB, RAID built was a job that could be completed in 10 minutes or even more than 10 minutes, which was not yet a problem without special concern. However, as disk capacity grows to hundreds of GB and even TB, RAID rebuild times have increased to hours or even days, it becomes a major problem in storage management.

For example, a traditional RAID 5 with 8 and 1 parity on 6TB NL-SAS disk drives takes 2.5 days to rebuild data. The rebuild process consumes system resources, reducing the overall performance of the application system. If users restrict the rebuild priority, the rebuild time will be even longer. The important of all, during time-consuming rebuilding, a large number of access operations could cause the failure of other disk drives in the pool, greatly increasing the probability of disk failure and the risk of data loss.

Limitations of Traditional RAID Architecture

The traditional RAID architecture is composed of a certain number of disk drives which are selected to form a disk group (also known as RAID group). You may also assign some disk drives as idle hot spare disk drives. A storage pool is grouped to provide capacity for volumes, and then finally map the LUN to the host to become the storage space on the host.

There are several limitations in such RAID architecture:

- First of all, when a disk drive of the disk group is damaged and the rebuild is required, only the member disks of the disk group participates in the rebuild job, and the data writing loading at the time is concentrated on the spare disk to form a bottleneck.
- Second, volume data access is limited to the member disks belonging to a disk group; this restricts the performance available to the host because the storage is executing both accessing and rebuilding I/O.

Why RAID Rebuild Time-Consuming

As drive capacity grows, RAID rebuild time grows linearly, raising the rebuild time required by traditional RAID architectures to tens of hours when using RAID disks with more than 4TB HDD capacity.

There are several factors that affect the RAID rebuild time:

- **HDD Capacity:** The HDD capacity makes up the disk group, the larger the HDD capacity, the longer the rebuild time is required.
- **Quantity of Disk Drives:** The quantity of disk drives included in a disk group affects the amount of time it takes for the system to read data from the remaining healthy disk

drives and write them to the hot spare disk drives. The more disks, the longer the rebuild time.

- **Rebuild Job Priority:** During RAID rebuild, the system still has to assume I/O access to the front-end host. The higher the priority assigned to the RAID rebuild job, the faster the rebuild, but the less the front-end host gains I/O performance.
- **Fast Rebuild:** Enabling fast rebuild function only need to rebuild the actual capacity of the volume, unused disk group space has not to rebuild. If only part of the space in a disk group is used by the volume, the rebuild time will be shortened.
- **RAID level:** RAID 1 and RAID 10 with direct block-to-block replication will rebuild faster than RAID 5 and RAID 6 with parity calculations.

Given the potential for failure on each disk drive, the more disk drives contain in a disk group, the more possibility of cumulative failure increase, so there is an upper limit on the quantity of disk drives in a disk group. Compared with the previous factors, the increasing impact of the disk drive capacity on the rebuild speed has become the primary factor. Such a long rebuild time is apparently not acceptable to any user. To solve the problems of traditional RAID, we implement RAID EE technology.

Theory of Operation

RAID EE adds more spare disks in a disk group, we call them **RAID EE spares** to separate the original global, local, and dedicated spares. Spare areas are preserved in each stripe of the disk group and are distributed in the disk group by means of disk rotation. When disks have failed in the disk group, missing data is rebuilt into the preserved spare areas. Since all disks in the set are destination of rebuilt data, the bottleneck of traditional RAID rebuild is gone, rebuild performance dramatically improved. If new disks are added in, data in spare areas are copied back to new joined disks.

Four new RAID levels are provided for RAID EE, there are:

- **RAID 5EE** (E stands for Enhanced), requires a minimum of 4 disk drives with one RAID EE spare disk which can tolerate 2 disk drives failure. Adding more RAID EE spares will tolerate more disk drives failure.
- **RAID 6EE** requires a minimum of 5 disk drives.
- **RAID 50EE** requires a minimum of 7 drives.
- **RAID 60EE** requires a minimum of 9 drives.

INFORMATION:
The RAIDEEspare quantity in a disk group is 1 to 8 disk drives.

Example of RAID 5EE with 1 RAID EE spare

Now we take an example to describe how it works. The following example is a RAID 5EE with 5 disks. 4 disks are for RAID disks, and additional one disk is for RAIDEEspare. After initialization, data block distribution is as follows . P is stands for parity, S is stands for RAID EEspare, and it is empty now.

D1	D2	D3	D4	D5
1	2	3	P	S
S	4	5	6	P
P	S	7	8	9
10	P	S	11	12
13	14	P	S	15

Assume that disk 2 has failed. RAID 5EE is under degraded mode.

D1	D2	D3	D4	D5
1	2	3	P	S
S	4	5	6	P
P	S	7	8	9
10	P	S	11	12
13	14	P	S	15

The spare areas are rebuilt with data from the failed disk drive. This action is called **EE Rebuild**. After rebuild, data distributed is like RAID 5 and it can tolerate another failed disk drive. As we can imagine, the more RAIDEE spare disks, the faster it rebuilds.

D1		D3	D4	D5
1		3	P	2
4		5	6	P
P		7	8	9
10		P	11	12
13		P	14	15

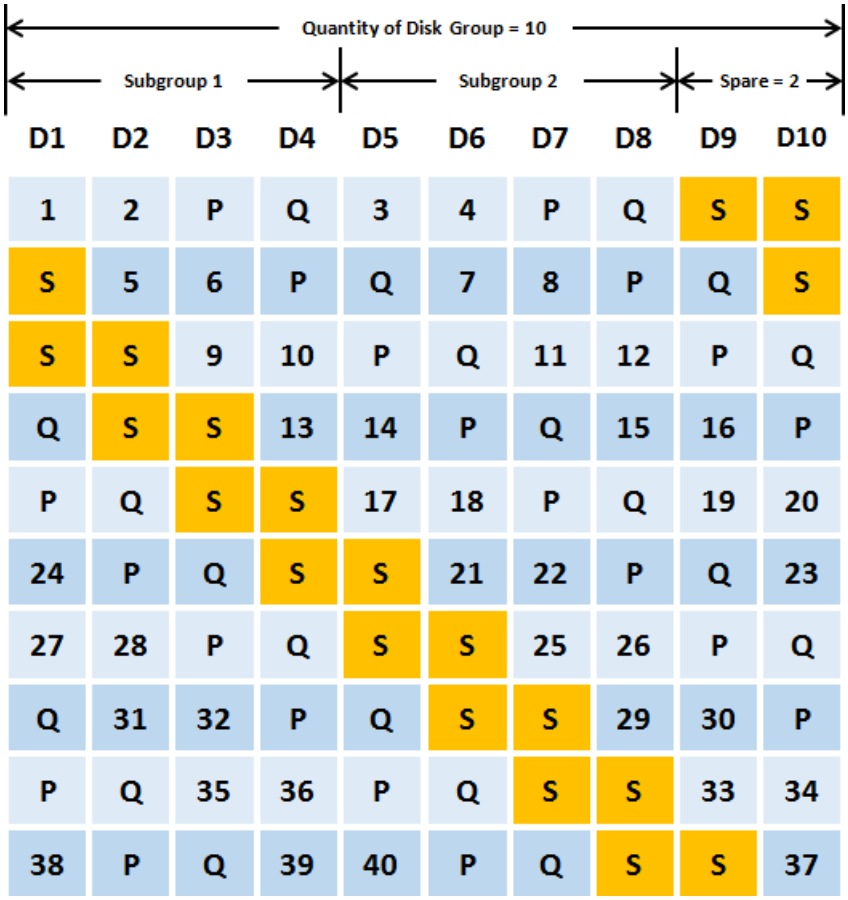
When a new disk drive is joined into the RAIDEE disk group, the data rebuilt in the spare area will be copied back to the new disk. This action is called **Copyback**.

D1	D2	D3	D4	D5
1	2	3	P	S
S	4	5	6	P
P	S	7	8	9
10	P	S	11	12
13	14	P	S	15

After copied back, it is back to RAID 5EE normal state.

Example of RAID 60EE with 2 RAID EE spares

Take another example of a RAID 60EE with 10 disks. 8 disks are for RAID disks, and 2 disks are for RAID EE spares. After initialization, data block distribution is as follows .



Rebuild and copy back of RAID 60EE is similar as the above; it will not be repeated here.

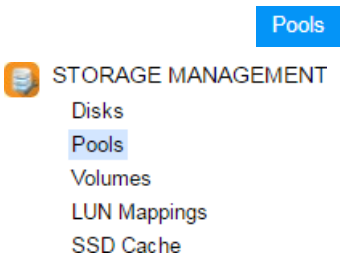
RAID EE Level Summary

The following is the summary of the RAID EE levels.

	RAID 5EE	RAID 6EE	RAID 50EE	RAID 60EE
Min. # Drives	4	5	7	9
Fault Tolerance (G = subgroups, S = RAID EE spares = 1 ~ 8)	2 ~ 9 drive failures (e.g., 1 (RAID 5)+ S spares)	3 ~ 10 drive failures (e.g., 2 (RAID 6) + S spares)	G+1 ~ G+8 drive failure (e.g., 2 subgroups (RAID 50) + S spares)	2xG+1 ~ 2xG+8 drive failures (e.g., 2x2 subgroups (RAID 60) + S spares)
Read Performance	Very Good	Very Good	Very Good	Very Good
Write Performance	Good	Fair to Good	Good	Fair to Good
Capacity (N = drive quantity, M = drive capacity, G = subgroups, S = RAIDEE spares)	(N-1-S) x M (e.g., (10 drives – 1 – 2 spares) x 1TB = 7TB)	(N-2-S) x M (e.g., (10 drives - 2 - 2 spares) x 1TB = 6TB)	(N-G-S) x M (e.g., (10 drives - 2 subgroups - 2 spares) x 1TB = 6TB)	(N-2xG-S) x M (e.g., (10 drives - 2x2 subgroups - 2 spares) x 1TB = 4TB)
Capacity Utilization (Min. ~ 26 drives)	18%~ 92% (e.g., 7/10 = 70%)	17%~ 88% (e.g., 6/10 = 60%)	29%~ 88% (e.g., 6/10 = 60%)	25%~ 80% (e.g., 4/10 = 40%)
Typical Applications	Data warehouse, Web service, Archive	Data archive, High Availability solution, Server with large capacity requirement	Large database, File server, Application server	Data archive, High Availability solution, Server with large capacity requirement

Configure RAID EE Pools

This section will describe the operations of configuring a RAID EE pool.

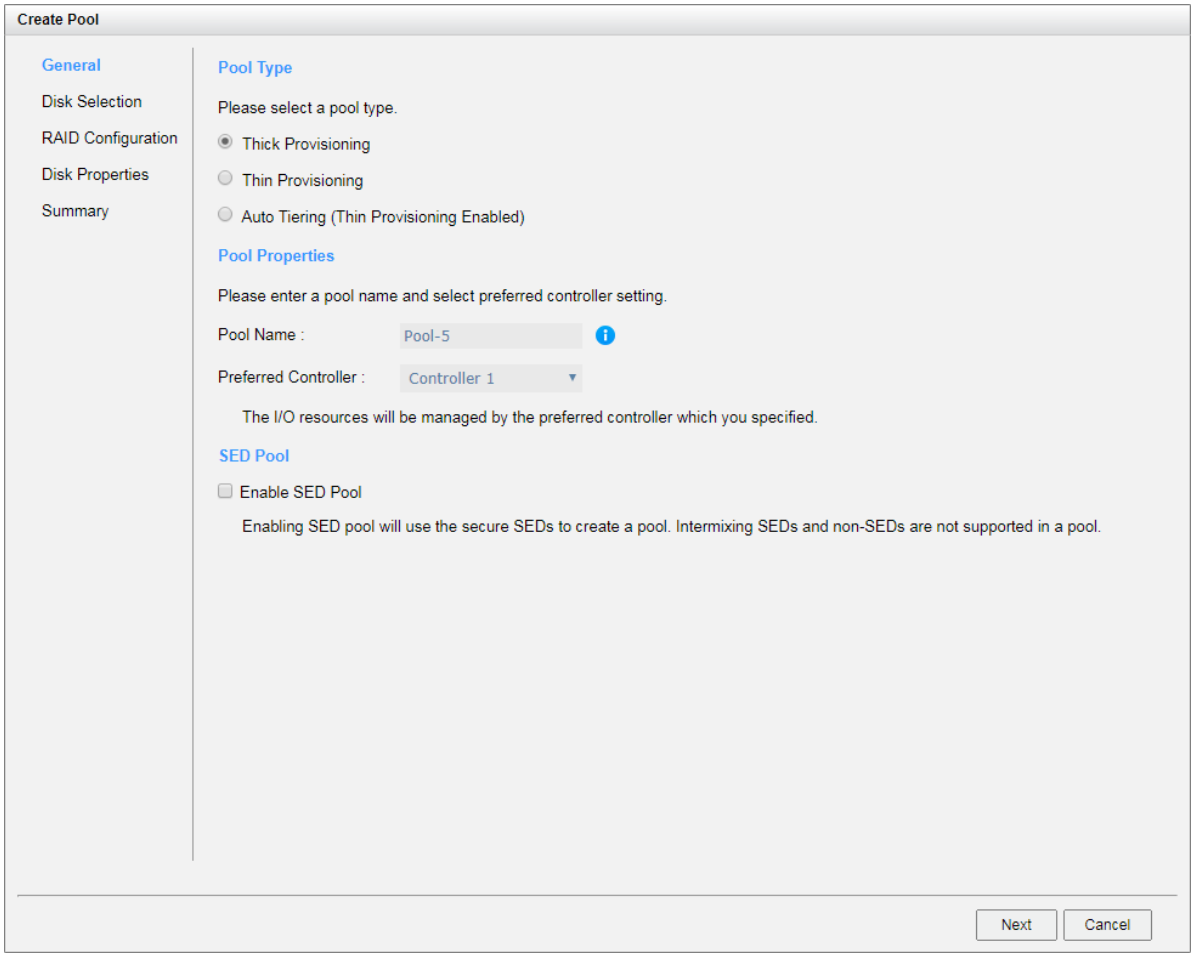


Create a RAID EE Pool

Here is an example of creating a RAID EE pool with 4 disks configured in RAID 5EE. At the first time of creating a pool, it contains a disk group and the maximum quantity of disk in a disk group is 64.

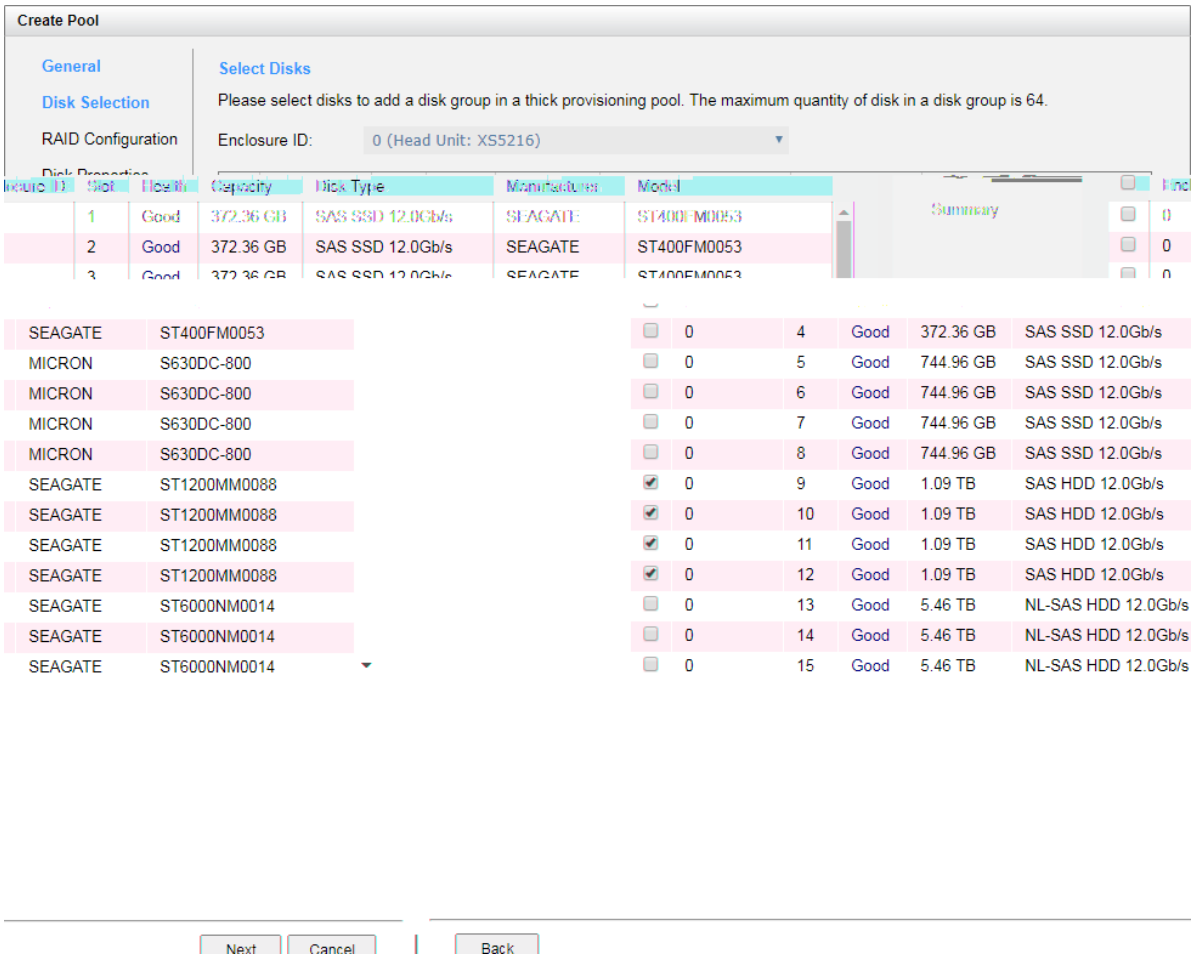
1. Select the **Pools** function submenu, click the **Create Pool** button. It will scan available disks first.

TIP:
It may take 20 ~ 30 seconds to scan disks if your system has more than 200 disk drives. Please wait patiently.

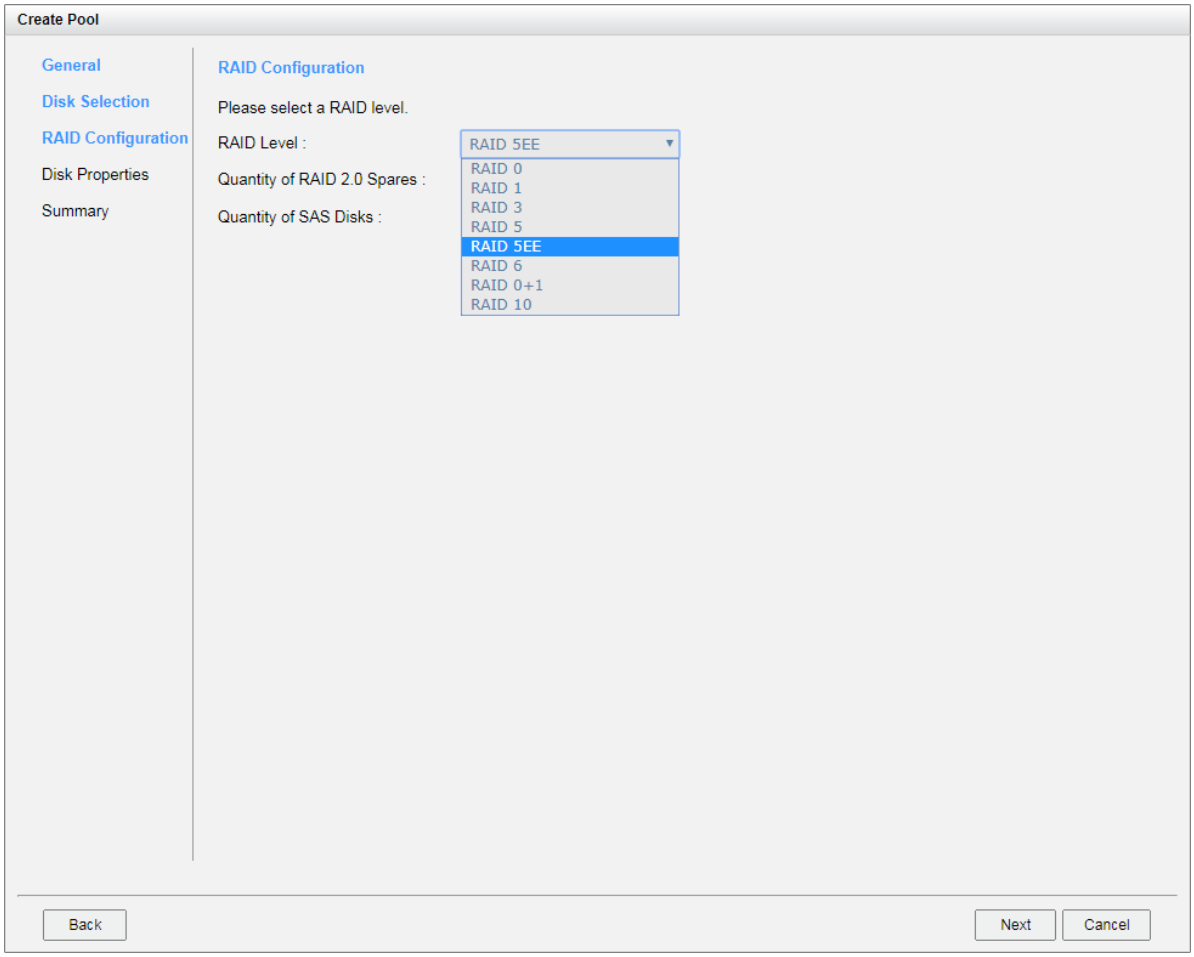


2. Select a **Pool Type**.

3. Enter a **Pool Name** for the pool. Maximum length of the pool name is 15 characters. Valid characters are [A~Z | a~z | 0~9 | -_<>].
4. Select a **Preferred Controller** from the drop-down list. The backend I/O resources in this pool will be processed by the preferred controller which you specified. This option is available when dual controllers are installed.
5. Check the **Enable SED Pool** checkbox. Enabling SED pool will use the secure SEDs to create a pool. Intermixing SEDs and non-SEDs are not supported in a pool.
6. Click the **Next** button to continue.



7. Please select disks for pool. The maximum quantity of disk in a disk group is 64. Select an **Enclosure ID** from the drop-down list to select disks from expansion enclosures.
8. Click the **Next** button to continue.



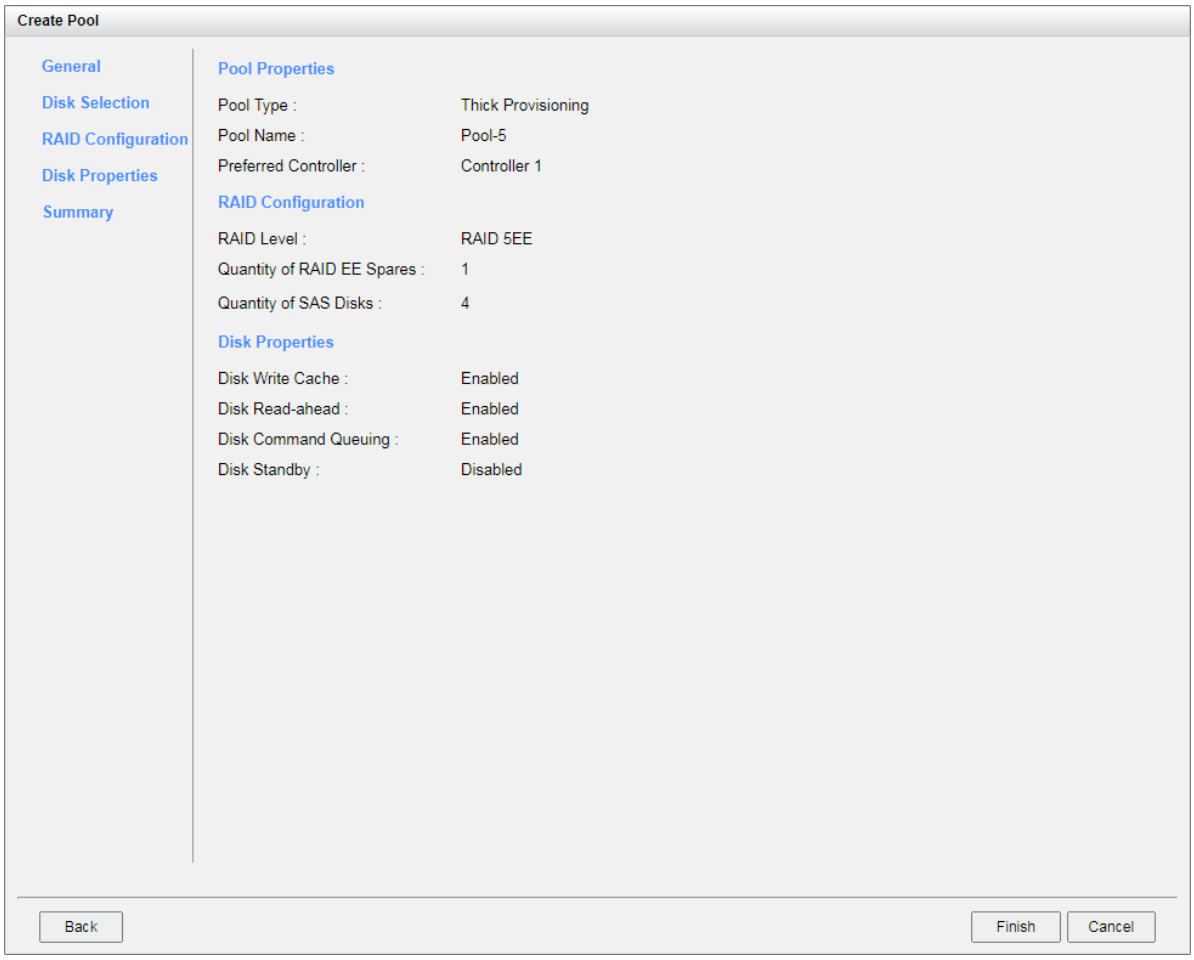
9. Select a **RAID Level** from the drop-down list which lists available RAID level only according to the disk selection. Then select a **Quantity of RAID EE Spares** if the RAID EE level is selected. And also select a **Quantity of Subgroups** if the combination RAID level is selected.
10. Click the **Next** button to continue.

11. Disk properties can also be configured optionally in this step :

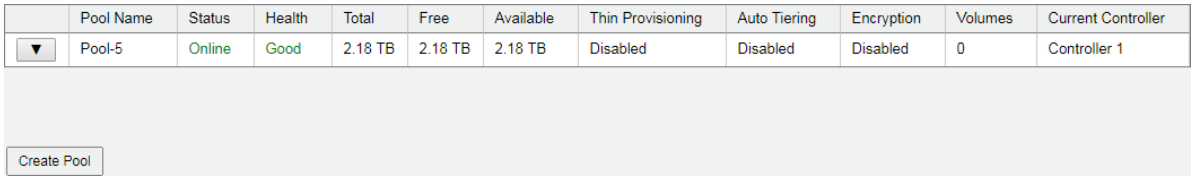
- **Enable Disk Write Cache**: Check to enable the write cache option of disks. Enabling disk write cache will improve write I/O performance but have a risk of losing data when power failure.
- **Enable Disk Read-ahead**: Check to enable the read-ahead function of disks. System will preload data to disk buffer based on previously retrieved data. This feature will efficiently improve the performance of sequential data retrieved.
- **Enable Disk Command Queuing**: Check to enable the command queue function of disks. Send multiple commands to a disk at once to improve performance.
- **Enable Disk Standby**: Check to enable the auto spin down function of disks. The disks will be spun down for power saving when they are idle for the period of time specified.
- **Enable High Latency Disk Warning**: Check to enable the high latency disk warning function in a disk group. When a disk drive is abnormal with high latency, the system

will send event logs to notify IT administrators in advance to avoid affecting overall performance.

12. Click the **Next** button to continue.



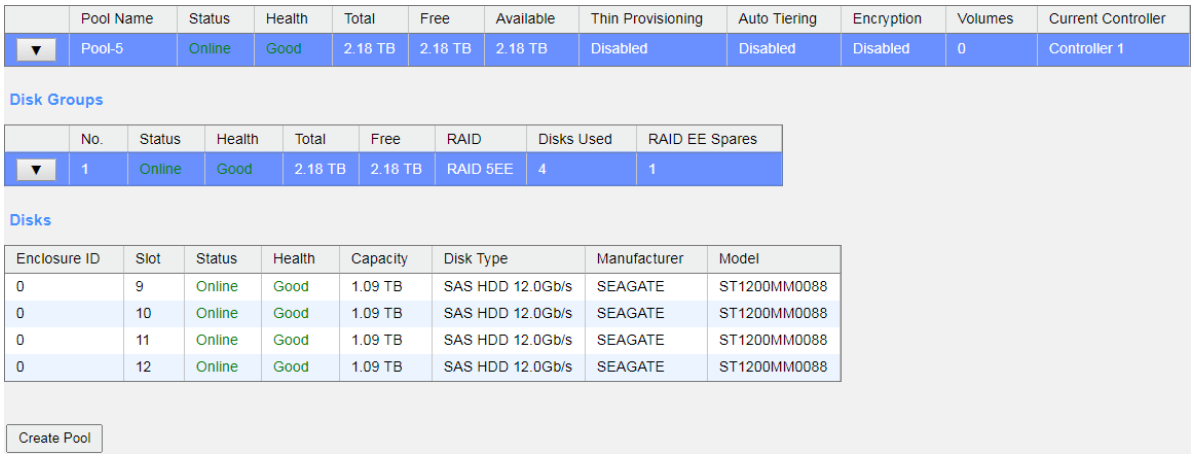
13. After confirmation at summary page, click the **Finish** button to create a pool.



14. A pool has been created. If necessary, dick **Create Pool** button again to create others.

List RAID EE Pools

Click a pool; it will display the related disk groups. Similarly, click a disk group; it will display the related disk drives. The pool properties can be configured by clicking the functions button ▼ to the left side of the specific pool.



This table shows the column descriptions.

Column Name	Description
Pool Name	The pool name.
Status	The status of the pool: • Online: The pool is online. • Offline: The pool is offline. • Rebuilding: The pool is being rebuilt. • Migrating: The pool is being migrated. • Relocating: The pool is being relocated. • EE Rebuilding: The pool is being RAID EE rebuilt.
Health	The health of the pool: • Good: The pool is good. • Failed: The pool has failed. • Degraded: The pool is not healthy and not complete. The reason

	could be missing or failed disks.
Total	Total capacity of the pool.
Free	Free capacity of the pool.
Available	Available capacity of the pool.
Thin Provisioning	The status of Thin provisioning: • Disabled: The pool is thick provisioned. • Enabled: The pool is thin provisioned.
Auto Tiering	The status of Auto Tiering: • Disabled: The pool is auto tiering disabled. • Enabled: The pool is auto tiering enabled. • Not Supported: The pool contains the disk groups with mixed disk type.
Encryption	The Data Secure Mode: • Disabled: The pool is not encrypted. • Enabled: The pool is encrypted.
Volumes	The quantity of volumes in the pool.
Current Controller ( )	The current running controller of the pool.

Column Name	Description
No.	The number of the disk group.
Status	The status of the disk group: • Online: The disk group is online. • Offline: The disk group is offline. • Rebuilding: The disk group is being rebuilt. • Migrating: The disk group is being migrated. • Relocating: The disk group is being relocated. • EE Rebuilding: The disk group is being RAID EE rebuilt.
Health	The health of the disk group: • Good: The disk group is good. • Failed: The disk group has failed. • Degraded: The pool is not healthy and not complete. The reason

	could be missing or failed disks.
Total	Total capacity of the disk group.
Free	Free capacity of the disk group.
RAID	The RAID level of the disk group.
Disks Used	The quantity of disk drives in the disk group.
RAIDEESpare	The quantity of RAIDEEspare disk drives in the disk group. Traditional RAID level is display as N/A.

Column Name	Description
Enclosure ID	The enclosure ID.
Slot	The position of the disk drive.
Status	The status of the disk drive: • Online: The disk drive is online. • Missing: The disk drive is missing in the pool. • Rebuilding: The disk drive is being rebuilt. • Transitioning: The disk drive is being migrated or is replaced by another disk when rebuilding occurs. • Scrubbing: The disk drive is being scrubbed. • Check Done: The disk drive has been checked the disk health. • Copying Back: The disk drive is being copied back.
Health	The health of the disk drive: • Good: The disk drive is good. • Failed: The disk drive has failed. • Error Alert: S.M.A.R.T. error alerts. • Read Errors: The disk drive has unrecoverable read errors.
Capacity	The capacity of the disk drive.
Disk Type	The type of the disk drive: • [SAS HDD | NL-SAS HDD | SAS SSD | SATA SSD] • [12.0Gb/s | 6.0Gb/s | 3.0Gb/s | 1.5Gb/s]
Manufacturer	The manufacturer of the disk drive.
Model	The model name of disk drive.

Operations on RAID EE Pools

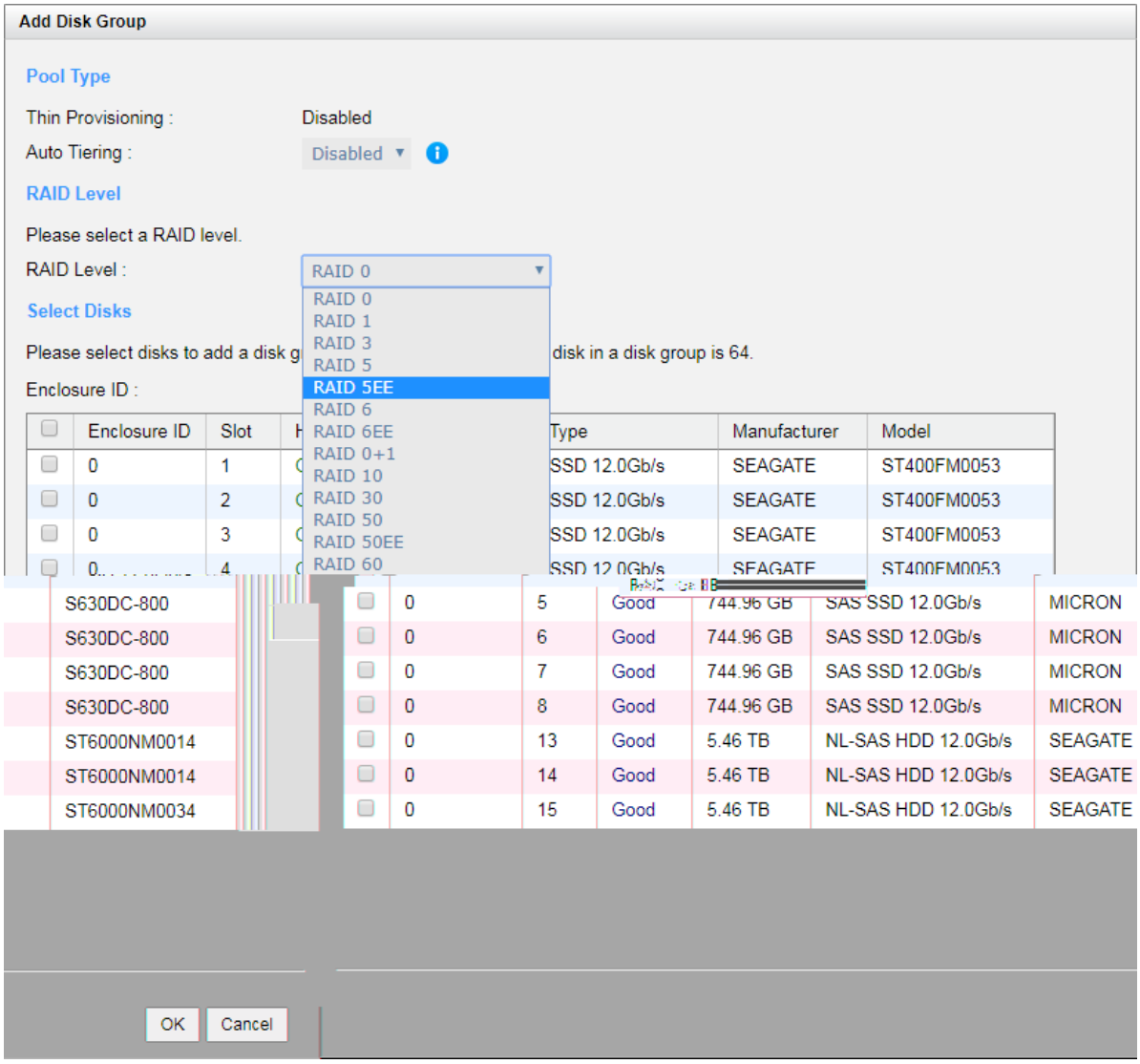
Most operations are described in the Configuring Storage Pools section in the XCubeSAN SANOS 4.0Software Manual. We describe the restrictions about RAIDEEpool in the following.

Verify Parity of the Pool

Click ▼ **-> Verify Parity** in one of pools to regenerate parity for the pool. It supports RAID level 3, 5, 6, 30, 50, 60 and RAIDEElevel 5EE, 6EE, 50EE, 60EE

Add a Disk Group into the Pool

Click ▼ **-> Add Disk Group** in one of pools to add another disk group into the pool. The new added disk group can be RAIDEElevel or traditional RAID level.For more information, please refer to the chapter 8.4.5, Add a Disk Group in a Thick Provisioning Pool section in the XCubeSAN SANOS 4.0Software Manual.

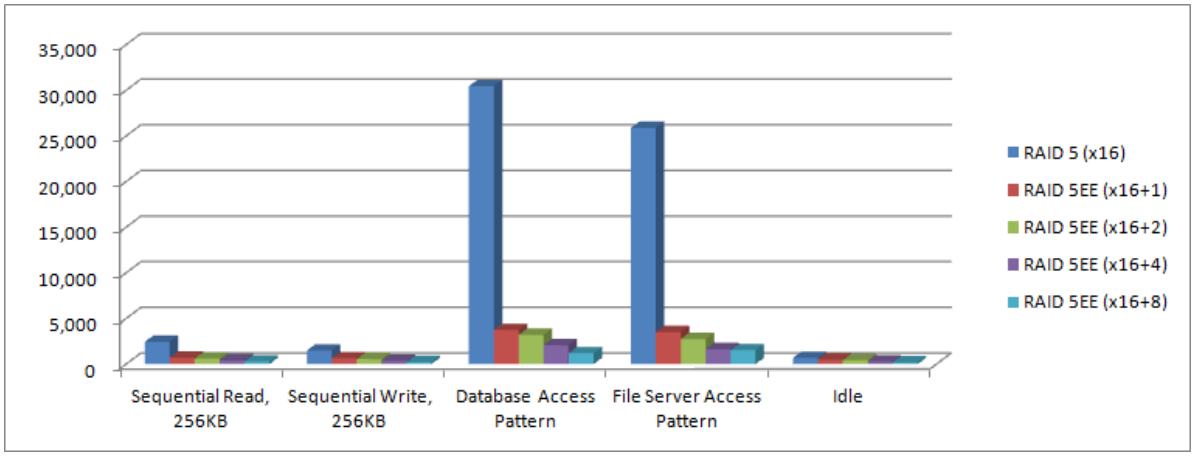


Migrate a Disk Group in a RAID EE Pool

The **Migrate Disk Group** function changes the disk group to a different RAID level or adds the member disks of the disk group to increase the capacity. A traditional RAID level can be migrated to RAID EE level, but RAIDEE level can be migrated to RAIDEE level only.

Test Equipments and Configurations

- Server
  - ä Model: ASUS RS700 X7/PS4 (CPU: Intel Xeon E5-2600 v2 / RAM: 8



Summary

- RAIDEEcan improve rebuild time by up to 96%.
- The more RAIDEEspare disks are used, theless rebuild time is.
- Rebuild time is more effective when there are reading accesses.
- If the access pattern is random, the copyback time is longer.
- When the data is copying back, the system resources will be reserved preferentially to the front end I/O.

Test Case 2: RAID 60 vs. RAID 60EE

This test provides the comparison of rebuild time and copyback time between RAID 60 and RAID 60EE. The same, we assume that the more RAIDEEspare disks will have less rebuild time and RAID 60EE willhave better efficiency.

Test Equipments and Configurations

- Server
  - Model: ASUS RS700 X7/PS4(CPU:Intel Xeon E5-2600 v2 / RAM: 8GB)
    iSCSI HBA:Intel 82574L Gigabit Network Connection
    OS: Windows Server 2012 R2
- Storage
  - Model: XCubeSAN XS5224D
    Memory: 16GB (2 x 8GB in bank 1 & 3) per controller
    Firmware 1.4.1

HDD: 24 x Seagate Constellation ES, ST500NM0001, 500GB, SAS 6Gb/s

- ä HDD Pool:
  RAID 60 Pool with 16 x NL-SAS HDDs in Controller 1
  RAID 60EE Pool with 17 (16+1 x RAIDEE spare) x NL-SAS HDDs in Controller 1
  RAID 60EE Pool with 18 (16+2 x RAIDEE spares) x NL-SAS HDDs in Controller 1
  RAID 60EE Pool with 20 (16+4 x RAIDEE spares) x NL-SAS HDDs in Controller 1
  RAID 60EE Pool with 24 (16+8 x RAIDEE spares) x NL-SAS HDDs in Controller 1
- ä HDD Volume: 1TB in Pool

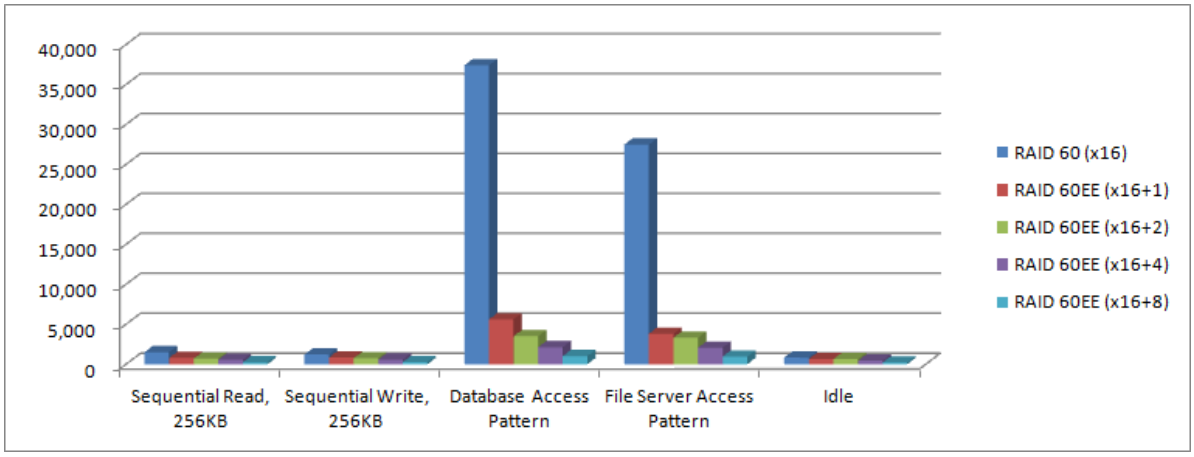
- I/O Pattern
  - ä Tool: IOmeter V1.1.0
  - ä Workers: 1
  - ä Outstanding (Queue Depth): 128
  - ä Access Specifications:
    Backup Pattern (Sequential Read / Write, 256KB (MB/s))
    Database Access Pattern (as defined by Intel/StorageReview.com, 8KB, 67% Read, 100% Random)
    File Server Access Pattern (as defined by Intel, refer to the Figure 16, http://www.storagereview.com/articles/200003/20000313OSandBM_5.html)
    Idle

- Test Scenario
  - ä First we create a RAID 60 pool. After initialization, plug out and then plug in one disk drive. Count the rebuild time with different I/O access patterns.
  - ä Continue to create RAID 60EE with 1 / 2 / 4 /8 x RAIDEE spare disks in sequence. After initialization, plug out one disk drive. The RAIDEE starts rebuilding. Count the rebuild time with different I/O access patterns. Then plug in one disk drive and set it as dedicated spare, it starts copying back. Last, count the copyback time.

Test Result

	RAID 60 (x16)	RAID 60EE (x16+1)	RAID 60EE (x16+2)	RAID 60EE (x16+4)	RAID 60EE (x16+8)
Sequential Read, 256KB	24'58"	13'04"	11'37"	9'23"	4'02"
Improved		48%	53%	62%	84%
Copyback		46'41"	41'38"	34'01"	35'43"
Sequential Write, 256KB	20'16"	13'59"	12'28"	9'40"	4'26"
Improved		31%	38%	52%	78%
Copyback		33'32"	44'33"	31'54"	35'04"
Database Access Pattern	623'22"	93'24"	58'17"	35'34"	16'52"
Improved		85%	91%	94%	97%
Copyback		843'11"	876'59"	492'25"	383'16"
File Server Access Pattern	458'03"	63'36"	55'23"	34'24"	15'51"
Improved		86%	88%	92%	97%
Copyback		1215'34"	1087'47"	673'21"	478'57"
Idle	13'47"	10'49"	10'50"	7'24"	3'30"
Improved		22%	21%	46%	75%
Copyback		26'46"	27'32"	29'30"	33'22"

Take an example, the rebuild time of RAID 60 with sequential read 256KB is24 minutes and 58 seconds. Compare to the RAID 60EE with1 x RAIDEEspare disks, the rebuild time is 13 minute and 4 seconds. It improves ((24 x 60 +58) - (13 x 60 + 4)) / (24 x 60 +58) = (1498 − 784) / 1498 = 0.4766 == 48%



Summary

- RAIDEEcan improve rebuild time by up to 97%.
- The more RAIDEEspare disks are used, the less rebuild time is.
- Rebuild time is more effective when there are reading accesses.
- If the access pattern is random, the copyback time is longer.
- When the data is copying back, the system resources will be reserved preferentially to the front end I/O.

Conclusion

As drive capacity grows, RAID rebuild time grows linearly. The more disk drives contain in a disk group, the more possibility of cumulative failure increase, so does the increasing impact of the disk drive capacity on the rebuild speed. Using RAIDEEtechnology will greatly reduce these risks.

Apply To

- XCubeSANXS5200 / XS3200 / XS1200 FW 1.4.1 and later

References

XCubeSAN SANOS 4.0 Software Manual

- XCubeSAN SANOS 4.0 Software Manual

Appendix

Related Documents

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

- All XCubeSAN Documents
- XCubeSAN QIG (Quick Installation Guide)
- XCubeSAN Hardware Manual
- XCubeSAN Configuration Worksheet
- XCubeSAN SANOS 4.0 Software Manual
- Compatibility Matrix
- White Papers
- Application Notes

Technical Support

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

- Via the Web: https://www.qsan.com/technical_support
- Via Telephone: +886-2-77206355
  (Service hours: 09:30 - 18:00, Monday - Friday, UTC+8)
- Via Skype Chat, SkypeID: qsan.support
  (Service hours: 09:30 - 02:00, Monday - Friday, UTC+8, Summer time: 09:30 - 01:00)
- Via Email: support@qsan.com