White paper

Fujitsu Storage ETERNUS DX Feature Set

This white paper provides an overview of the main features supported by the Fujitsu Storage ETERNUS DX hybrid series.

It highlights their benefits and use cases and briefly describes each feature.

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Introduction

As data is the most important asset in any company, storage system plays a vital role in the IT infrastructure of every enterprise. IT administrators need to ensure that data is stored on reliable, highly available platforms that can scale efficiently in order to handle ongoing business changes.

New IT trends are also imposing new challenges on storage systems. The increasing use of business analytics and data warehousing, the hype around big data, server, and desktop virtualization, the enormous growth of unstructured data are just a few of the examples.

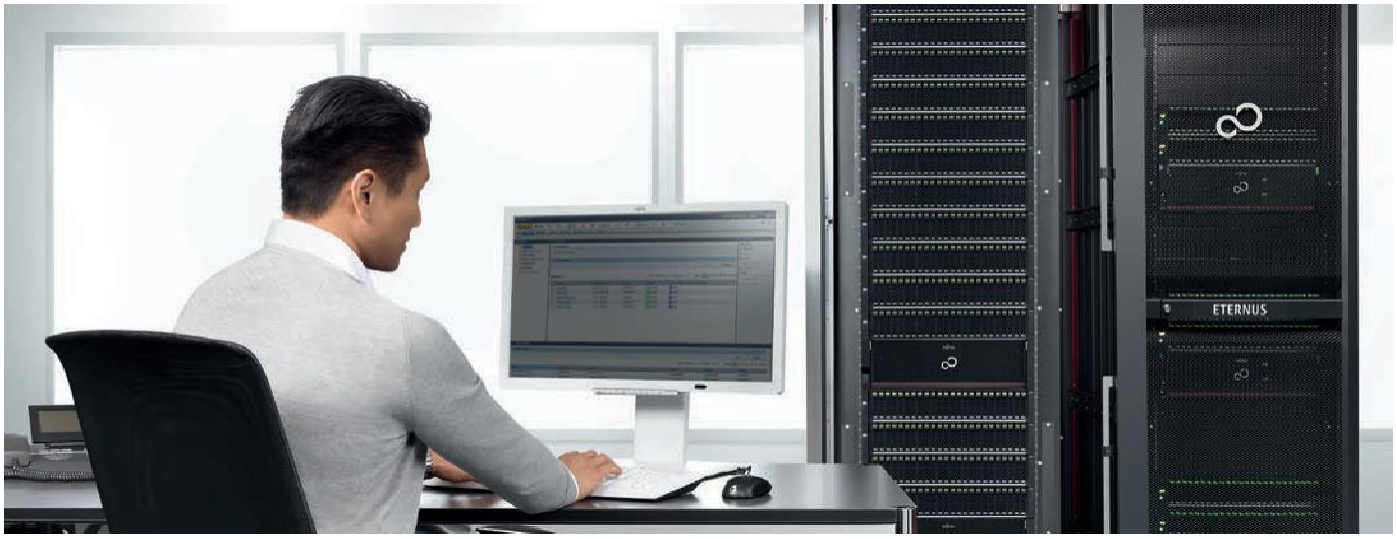
These trends not only require massive storage capacities, but also – and more importantly – storage performance. Parameters, such as IOPS (Input & Output Operations per Second), latency and bandwidth are gaining in significance. Many enterprises are purchasing additional storage systems, just to provide the required performance. The result is storage capacity overprovisioning as well as higher operational and capital expenditure.

These are the reasons why Fujitsu has designed Fujitsu Storage ETERNUS DX in a manner which makes it **Business-Centric Storage.** Built on a powerful performance architecture it ensures that there are no performance bottlenecks. It efficiently consolidates storage resources while keeping investments down to a minimum.

Higher processor performances, larger system caches, faster disk interfaces, networking connectivity, and ultra-fast flash storage are just some of the highlights within the ETERNUS online storage structure.

The ETERNUS SF Storage Management Software complements this with its simple setup and administration functionalities. The single pane of glass view ensures that an IT administrator, once trained to operate a specific system in the ETERNUS Hybrid Storage Arrays, will also be able to manage the other models.

Advanced software features, particularly for automated service management quality, helps to deliver predictable operations and stable response times for business-critical applications – at the right cost and with the right service levels.



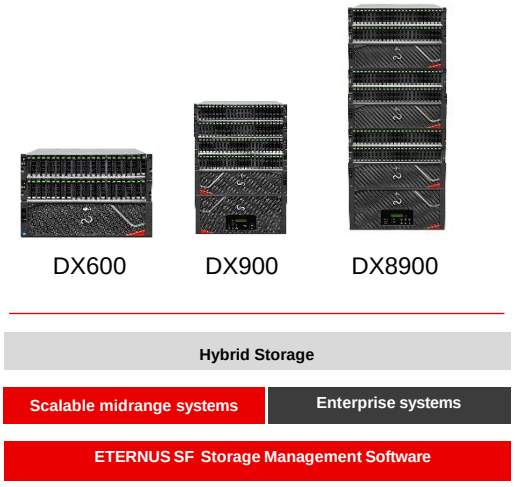
Hardware Architecture

Based on a unique and consistent system design, successfully tested for more than a decade, ETERNUS DX is a seamless architecture of hybrid disk storage systems ranging from midrange to enterprise class.

The main design principles of ETERNUS DX are scalability and flexibility. In order to provide a midrange storage solution that satisfies the needs of mid-size and big businesses where the performance and stability is key, the ETERNUS DX600 supports all the advanced functionalities to deliver reliable operations at an attractive price, along with easy-to-use storage management. In the highly demanding enterprise segment, the ETERNUS DX8900 provides peak loads of up to 10 million IOPS*. The superior performance of ETERNUS DX has been proven in various customer deployments and SPC benchmarks.

The scalable midrange models with enhanced performance architecture provide block access. All models within the same generation use the same types of disks, disk shelves, racks, cables, and other components. Only the controller module is unique to each model.

ETERNUS DX S6 generation will also introduce an end-to-end NVMe support at a later stage that will increase performance even more than before.



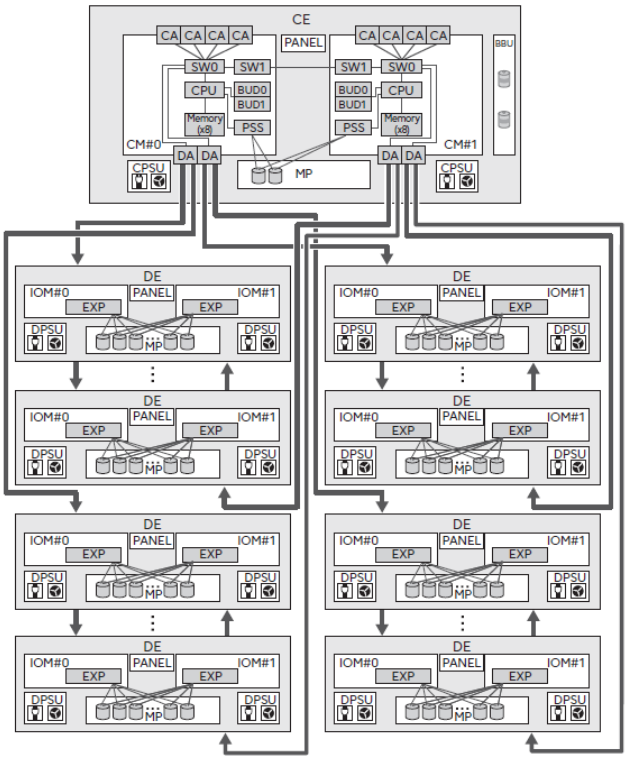
ETERNUS DX – Midrange Models

The midrange model ETERNUS DX600 is designed to provide capacity, performance, and reliability. It contains the following hardware:

Controller Enclosure (CE): The CE contains the Controller Modules (CM), Channel Adapters (CA), Battery Backup Unit (BBU) and Power Supply Units (PSU).

Drive Enclosures (DE): Expansion drive enclosures can be added according to the capacity required. Disk enclosures supporting 2.5” and 3.5” disk drives are available. In addition to SAS-based enclosures there is a 2.5” NVMe enclosure.

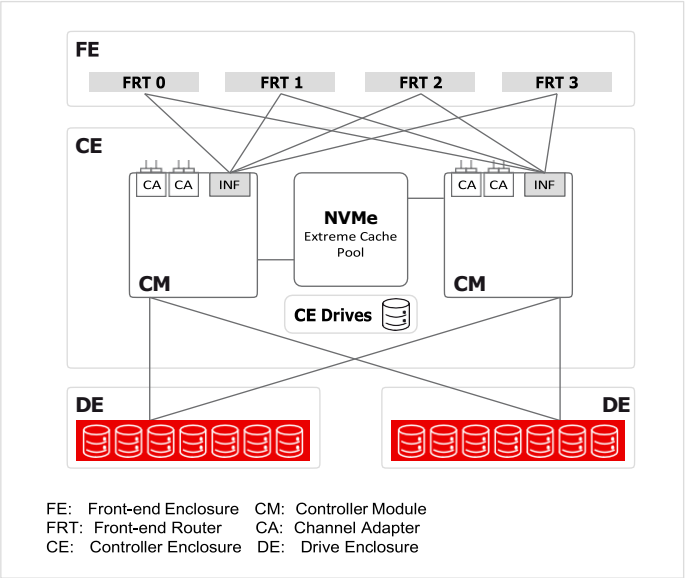
The basic architecture is shown below:



The basic architecture of the system consists of two interconnected CMs (via PCI Express), each having four Channel Adapters (CA), and two drive-side interfaces installed. It also supports high-speed PCI Express based NVMe drives – which provides higher performance with a smaller number of disk drives, optimizing costs and power consumption.

ETERNUS DX – Midrange and Enterprise Models

The schematic architecture of the midrange model ETERNUS DX900 and enterprise model ETERNUS DX8900 is shown below. This architecture deviates slightly from the other models. While most of the basic functional blocks are the same, the connection between the controller modules itself is realized in a different way:



In order to increase the availability of the system, an additional component, the Front-end Enclosure consisting of four Front-end Routers, is deployed. Each Controller Module is connected to all other Controller Modules via all four Front-end Routers. Thus, the interconnection of the Controller Modules is quadruplicated – this is called the **Quad Star Architecture.** With this architecture the systems can scale both performance and capacity over a wide range. The ETERNUS DX900 scales up to 4 Controller Modules while the ETERNUS DX8900 scales up to 24 Controller Modules, offering 137 PB of capacity.

In order to ensure reliable operation and high availability, all ETERNUS DX storage systems have a fully redundant configuration and hot maintenance capability. The interconnection of the CMs is duplicated in the entry and midrange models and quadruplicated via the FRTs in the enterprise models. A drive enclosure (DE) also has two independent interface ports that are directly connected to two CMs for path redundancy.

The use of redundant components and multiple controller-to-drive connections ensures exceptional reliability. Hardware components supporting hot-exchange and hot-expansion features not only enable firmware upgrades during system operation, but also provide capacity expansion together with the LUN expansion feature where DEs or HDDs are added as needed.

For more details on the enterprise model ETERNUS DX8900 S6, please refer to the following whitepaper:
ETERNUS DX8900 S6 Hardware Architecture

Interfaces

The ETERNUS DX provides different types of host interfaces, offering customers full flexibility in selecting the most appropriate data center infrastructure. Fibre channel is the most widely used storage networking technology as it is highly reliable, efficient, and secure. Up to 64 Gbps bandwidth is supported, offering the highest possible bandwidth.

1 Gbps & 10 Gbps iSCSI are also supported for connecting to IP networks. They are simple to operate and hence preferred by many customers. The backend interfaces are realized by 12 Gbps SAS or PCIe for NVMe disks.

Types of Disk Drives

As the storage requirements differ according to the type of data and the frequency of its usage, various types of disk drives need to be supported in order to allocate the right disks for each type of data. Some data is mission-critical; it has to be accessed immediately in order to avoid revenue loss or productivity degradation. This data must be stored on drives with very high performance, such as SSDs. On the other hand, some types of data do not require very high performance but need to be stored for longer periods; it can thus be stored on more cost-efficient, high-capacity disks such as Nearline SAS disk drives, enabling the customer to balance speed, capacity and costs.

In addition, 2.5” and 3.5” enclosures can be mixed in the same storage configuration of ETERNUS DX disk storage systems. SSD, SAS and Nearline SAS disks can be mixed in the same 2.5” drive enclosures. 3.5” enclosures can host Nearline disk drives, which provide up to 18 TB capacity.

In addition to manual tiering of data into the appropriate type of disk drives, the ETERNUS DX products supports Automated Storage Tiering (AST) as described in the chapter “ETERNUS SF Management Suite” of this white paper.

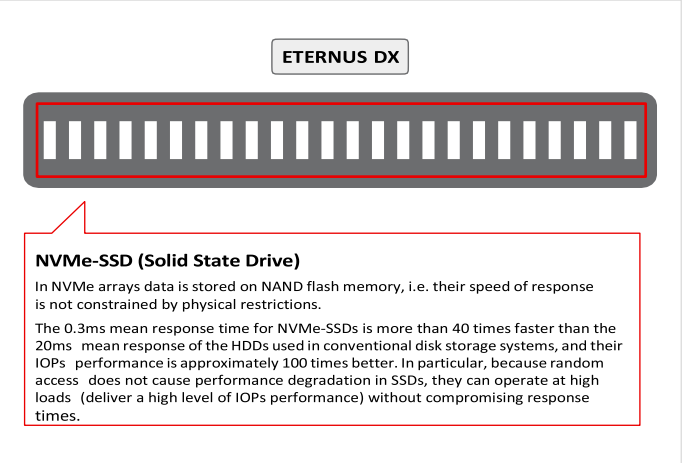
NVMe-SSDs

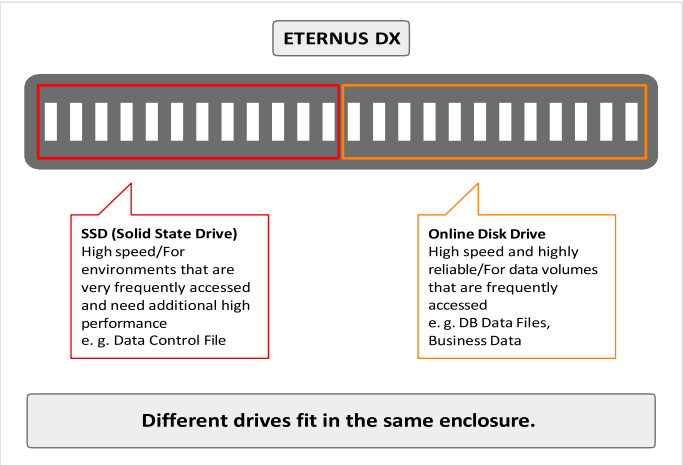
NVMe-SSDs (Non-Volatile Memory Express Solid State Drives) are pivotal in enterprise-class storage systems, offering unparalleled speed, efficiency, and reliability. With lightning-fast data transfer rates and ultra-low latency, NVMe-SSDs excel in high-performance computing environments, database management systems, and virtualization infrastructures. Their ability to handle massive workloads with exceptional throughput enhances overall system performance, reducing latency bottlenecks and accelerating data-intensive tasks. Enterprises leverage NVMe-SSDs to meet stringent service level agreements (SLAs), ensure seamless data access, and optimize resource utilization, thereby enhancing productivity and competitiveness in today's demanding business landscape.

Solid State Drives (SSD)

Solid State Drives (SSD) use semiconductor memory to store data. They contain no motors or moving parts, and thus have a much higher read/write access speed and reduced power consumption.

They benefit those applications with high random-access requirements, such as databases. In addition, with no motors or moving parts, they are more reliable than disk drives. The SSD used in ETERNUS DX have enterprise-class performance and reliability. While maintaining compatibility with traditional disk drives, they support low-power consumption and high-speed operation. If a power failure occurs, SSD in ETERNUS DX can move any data in the volatile memory of the SSD (high-speed DRAM cache) to the flash memory and ensure a safe system halt.





Online SAS Disk Drives

For data volumes that are frequently accessed, but still do not require the very high performance of SSD, SAS disk drives are used, providing a balanced mix of performance and capacity, while keeping costs at a moderate level.

Nearline SAS Disk Drives

Storing infrequently accessed data on high-performance storage devices generates unnecessary costs. To meet the growing demand for cost-effective storage of less frequently accessed data, Fujitsu provides high-capacity, highly reliable, yet cost-optimized Nearline disk drives in its ETERNUS DX disk storage systems. This combination of online disk drives and Nearline disk drives in the same drive enclosure enables ETERNUS DX disk storage systems to support cost-effective operations, such as disk-to-disk backup and long-term storage of reference data.

High-Density Drive Enclosures

High-density drive enclosures are available for ETERNUS DX disk storage systems in order to meet the growing demand for more capacity. They house up to 60 3.5” disk drives in one DE, which can provide up to 600 TB in 4 rack units.

Capacity Management

Thin Provisioning

Storage system growth continues year on year. Due to concerns about having sufficient storage capacity, users tend to deploy more physical storage than they actually need – "just to be safe." However, in practice the allocated capacity is often underutilized. Industry research organizations have even stated that in some cases only 20 percent to 30 percent of the provided capacity is actually used.

Thin provisioning technology has thus been developed to enable effective use of available storage capacity for better investment utilization. It reduces physical storage deployment by using virtual storage techniques that maximize available capacities.

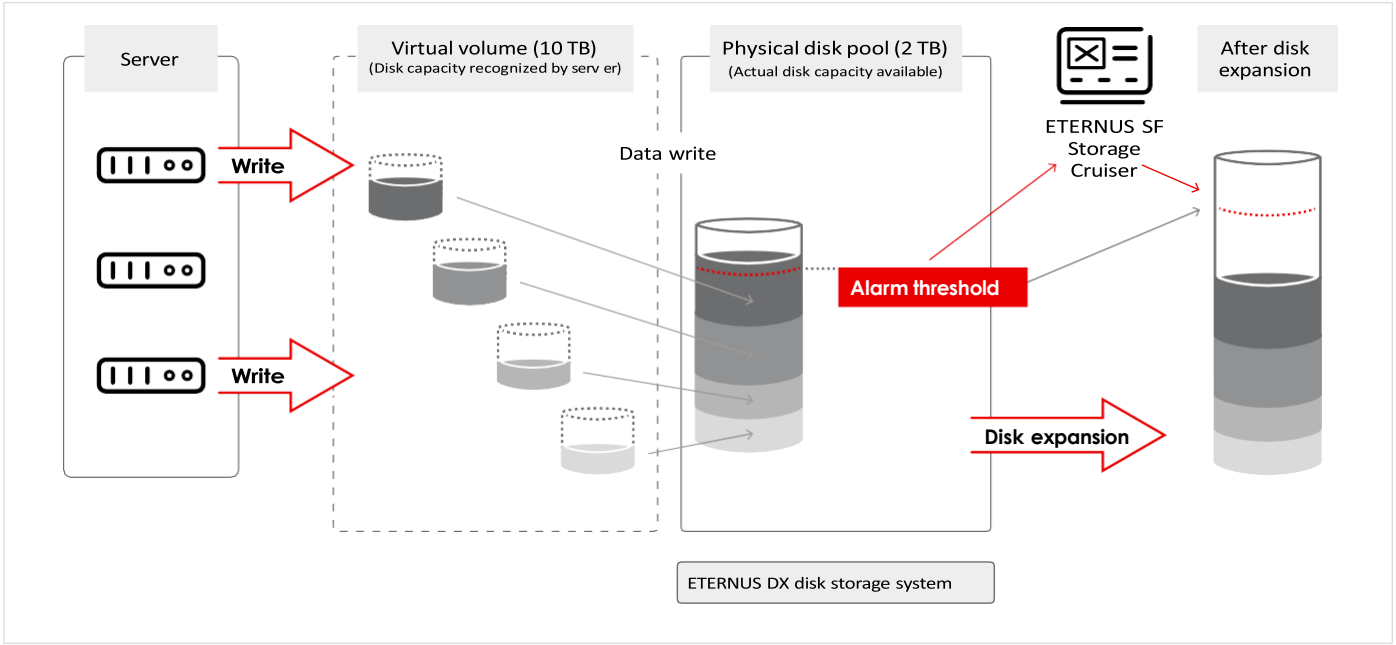
Thin provisioning only assigns the total overall user capacity as virtual storage. The actual physical disk capacity is allocated as and when needed. All physical disks are managed as a single disk pool and allocated according to the amount of data written to the virtual volumes. This reduces the amount of unused physical disk capacity and supports much more effective storage operations. Furthermore, predefined thresholds avoid storage capacity shortages by issuing a warning that additional physical disks must be added.

Example: A user requests 10 TB of resource allocation from the server administrator. While 10 TB of physical storage capacity may eventually be needed, current usage suggests that 2 TB of storage is sufficient.

The system administrator therefore prepares 2 TB of physical storage but allocates a 10 TB virtual volume to the server. This means that the server can start using the existing physical disk pool which is only around 1/5 of the virtual volume. This "start small" approach enables more effective use of storage capacity. Even though more physical capacity is required to support the virtual volume (as shown in the diagram), existing physical volume capacity is first consumed. In order to avoid a capacity shortage, the physical disk pool is monitored using a predefined usage threshold. For example, by defining 80 percent of the entire disk pool as the threshold, an alarm tells the administrator to expand the number of physical disks when that amount of 8 TB in our example is reached. This means that the new drives can be added without stopping the system, ensuring continuous business operation.

Benefits

- Lowers initial investment by using storage capacity very efficiently (start small)
- Does not require any changes to storage capacity settings for changes on demand
- Reduces operational costs by integrating storage with virtualization
- Reduces overall power consumption via reductions in over-provisioning



Deduplication/Compression

ETERNUS DX systems provide advanced data reduction technologies in combination with flexible configuration options. ETERNUS DX600, ETERNUS DX900 and ETERNUS DX8900 feature a dedicated Storage Acceleration Engine (SAE), which provides hardware assisted function for deduplication and compression. This feature improves the capacity optimization by offloading the data reduction process into the dedicated SAE, thereby reducing the consumption of CPU resources.

Deduplication is a technology that automatically analyzes and eliminates duplicate data with the same content. The deduplication function can significantly reduce the amount of transferred data and save storage space during backup operations.

Compression is a technology that reduces the size of data and converts it to different pattern while maintaining its intrinsic characteristics. By reducing the size of the data that is to be saved, the compression function provides storage space efficiency.

The data size can be further reduced by effectively combining the deduplication and compression functions since the effectiveness of data size reduction depends on the type of data.

With deduplication, compression and thin provisioning, the SSD capacity needed can be reduced by an average factor of five for typical use cases. Data reduction technologies can be adjusted on the basis of storage volumes to balance performance and cost accordingly to application SLAs.

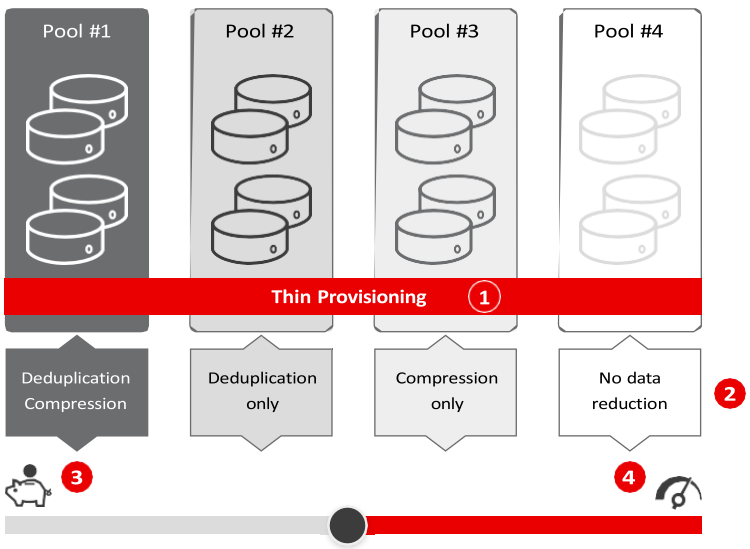
The Deduplication/Compression function analyzes duplicated data in every 8 KB of the write data from the server and writes the duplicated data only once. After the first write, the data is referenced instead of writing the same data again. This reduces the total write size. Also, with the compression function further data reduction is realized.

Storage Compression in the enterprise storage system ETERNUS DX8900 improves capacity optimization by offloading the data reduction process into a dedicated Storage Acceleration Engine (SAE), thereby reducing the consumption of CPU resources. To optimize compression in database environments, the unit of the compression process adopted is 8 KB. The compression process is performed across multiple CMs (24 CMs in maximum configuration): thus, the performance of the compression process improves in proportion to the number of CMs.

Benefits

- Effective storage capacity extended by factor 5[1]
- Flexible configuration options
  - Decide on application SLA (volume basis) whether to use or not
- Reduced amount of data writes to SSDs to extend their life span
- Significantly improved storage efficiency of SSD

1 Heavily dependent on use case
2 Calculation based on deduplication/compression factor of five



Use finely granulated options to balance performance and efficiency for your applications

1. Thin Provisioning is turned on by default
2. Decide on a per application level which option provide the best results
3. Deduplication in combination with compression provides highest ef ficiencies
4. Keep data reduction off for applications with performance SLAs

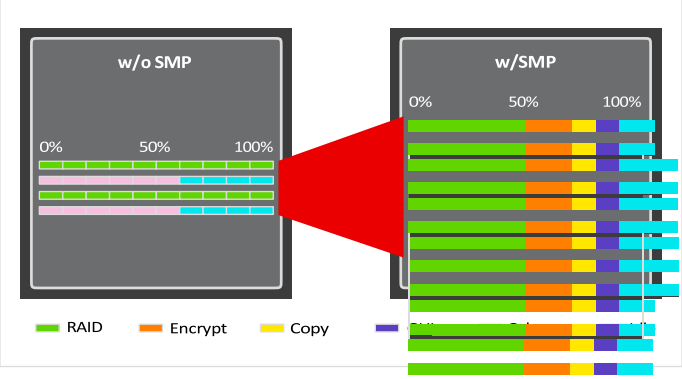
Performance Management

Symmetric Multi-Processing and 64-bit Operating System

ETERNUS DX systems use powerful Intel® multi-core processors to provide leading performance.
Symmetric multi-processing is a technology that allows controlling multiple processor cores by one operating system. Combined with using the latest 64-bit operating system, it offers many benefits, such as:

- Memory resources are better utilized
- Performance is dramatically increased as the core sufficiency ratio is improved by sorting required transactions flexibly even when cores are increased
- Better resource optimization as resources are not bound to cores
- Higher flexibility and processing performance as 64-bit operating system CPU can handle high-volume data

The figure below shows the benefit of symmetric multi-processing, as many different tasks can be executed in parallel, resulting in significant performance increase.



Extreme Cache Pool

The overall performance of a storage system can be dramatically increased by using flash technology like NVMe`s; this implies that all user data is placed on NVMe`s which would make the array quite expensive.

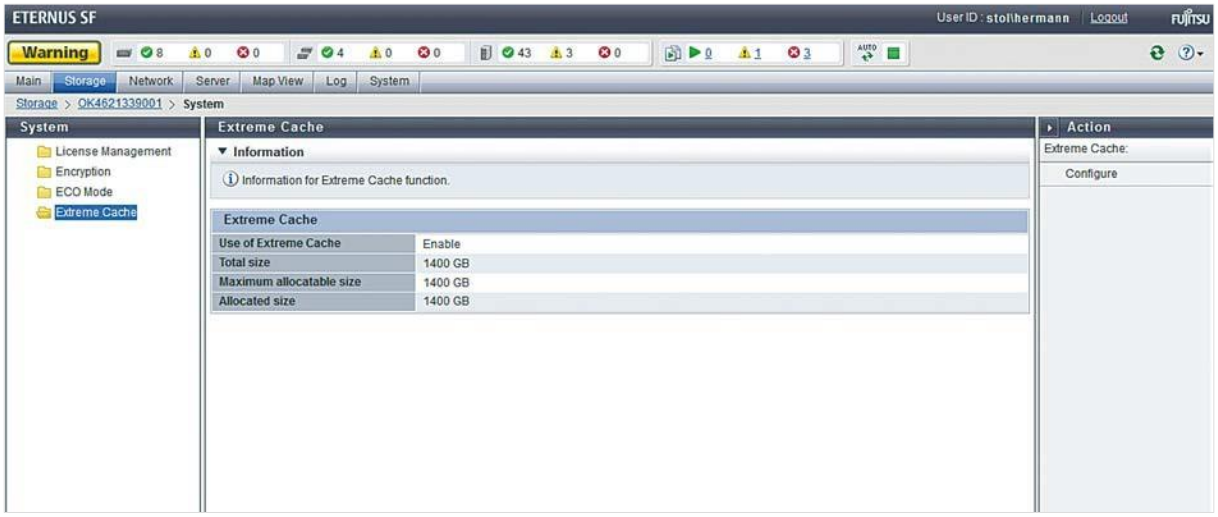
ETERNUS DX series offer additional approach to boost performance without stressing the budget too much. Both are reducing the need to invest in many SSDs or additional spindles (to achieve a required number of IOPS).

Extreme Cache Pool – High-Speed NVMe SSD Read Cache in Disk Enclosure

Extreme Cache Pool greatly speeds up read operations, depending on the workload. NVMe`s in the disk shelves provide additional read cache.

The ETERNUS DX600 S6, ETERNUS DX900 S6 and ETERNUS DX8900 S6 support Non-volatile Memory Express (NVMe) secondary cache (also called the NVMe Extreme Cache Pool), which is located directly within the Controller Enclosure (CE) or NVMe Drive Enclosure and can be accessed by both controller modules of the CE. There is one NVMe drive: 3.2 TB.

Each controller module can take two modules and both controller modules have to be equipped identically. Extreme Cache Pool is available for all or dedicated LUNs, allowing to boost performance of dedicated applications as required by the business. Thus, LUNs built from cheaper HDD's instead of SSD's can benefit from drastically increased performance by use of NVMe accelerated Extreme Cache Pool.



Extreme Cache Pool operations

With the ETERNUS DX series an additional storage tier, called Extreme Cache Pool was implemented in the midrange and enterprise storage arrays. It consists of flash memory located either in the controller enclosure or drive enclosure offering low latency access to cache data. With ETERNUS SF with just a few clicks the usage of Extreme Cache Pool can be enabled or disabled globally for the array or very granularly for single volumes. The read cache hit ratio is constantly monitored and can be visualized on the performance graph for RAID groups and volumes.

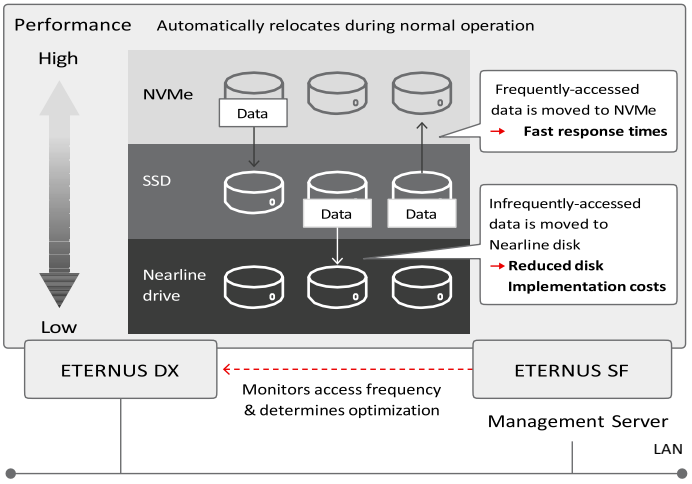
Automated Storage Tiering (AST)

Different applications have various requirements, just as different user groups have various needs. From an IT administrator's point of view, if the access points for the requests coming from these applications and users are not designed optimally, this will lead to latency in mission critical applications, followed by complete chaos. Moreover, storage capacity will not be utilized effectively, meaning that capacity enhancement or better performance will be demanded.

This is where automated storage tiering can help. AST monitors data access frequency in mixed environments that contain different storage classes and disk types. The storage administrator does not need to classify data or define policies.

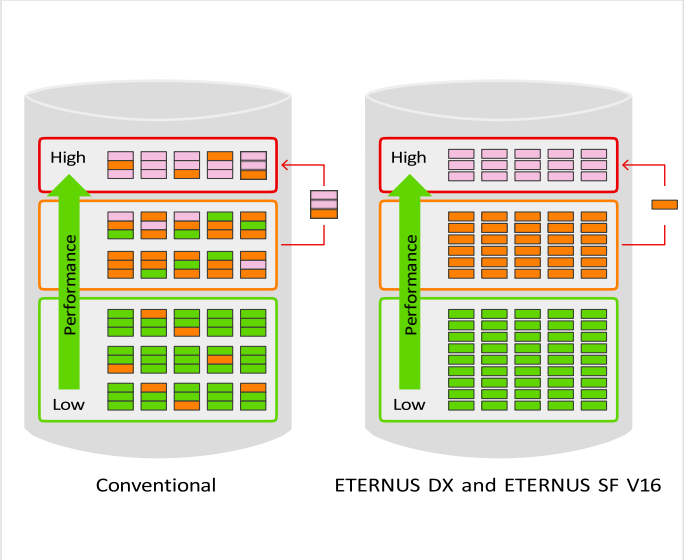
Once the tiers are configured, the ETERNUS DX storage system does all the work, enabling the storage administrator to focus on other storage-related responsibilities. The automation of tiered storage means that multiple storage tiers can be managed as a single entity. It helps ensure that the right data is in the right place at the right time.

ETERNUS SF controls the destination and the arrangement of data, monitors its access frequency, and automatically relocates the data between drives to the most appropriate storage devices. This storage hierarchy control offers significant investment optimization and reduces storage costs by matching storage system capabilities and applications sensitivity to performance, availability, price, and functionality. Infrequently used data and non-essential copies of primary application data, e.g., point-in-time snapshots, replication copies and data mining are located on Nearline drives, which have large capacity but are less expensive. For high priority applications, the best performance and response times for important information are improved by locating frequently accessed data on high-performance SSD. The overall arrangement of data on the different drive types is thus optimized regarding costs. The relocation of data is completely transparent to servers and applications and is carried out without any changes in server settings.



Data can be moved in 252 MB chunks providing high efficiency, as less data with low performance requirements would unnecessarily be moved to faster, more expensive disk drives. On the other hand, it guarantees that data demanding high performance will be moved to the fastest disk drives.

Calendar-based scheduling enables the exclusion of off-day performance, such as weekends and public holidays, from the tuning process.



Benefits

- Reduces data management time and costs due to automated operations
- Provides optimal performance while reducing costs
- Operational data reallocation policies can be flexibly set to meet requirements
- Reallocations are performed without changes in server settings

Application I/O Prioritization – Quality of Service (QoS)

A prerequisite for any storage consolidation strategy is the ability to host multiple applications on a single storage platform without allowing the actions of one set of users to affect the I/O performance of others.

Potential problem areas for shared storage access include:

- Workloads with I/O and cache conflicts, such as online transaction processing (OLTP) and data warehousing
- Tiered storage access restrictions, such as development and production applications
- Peak processing demands for critical applications versus maintenance activities, such as backup or database reorganization

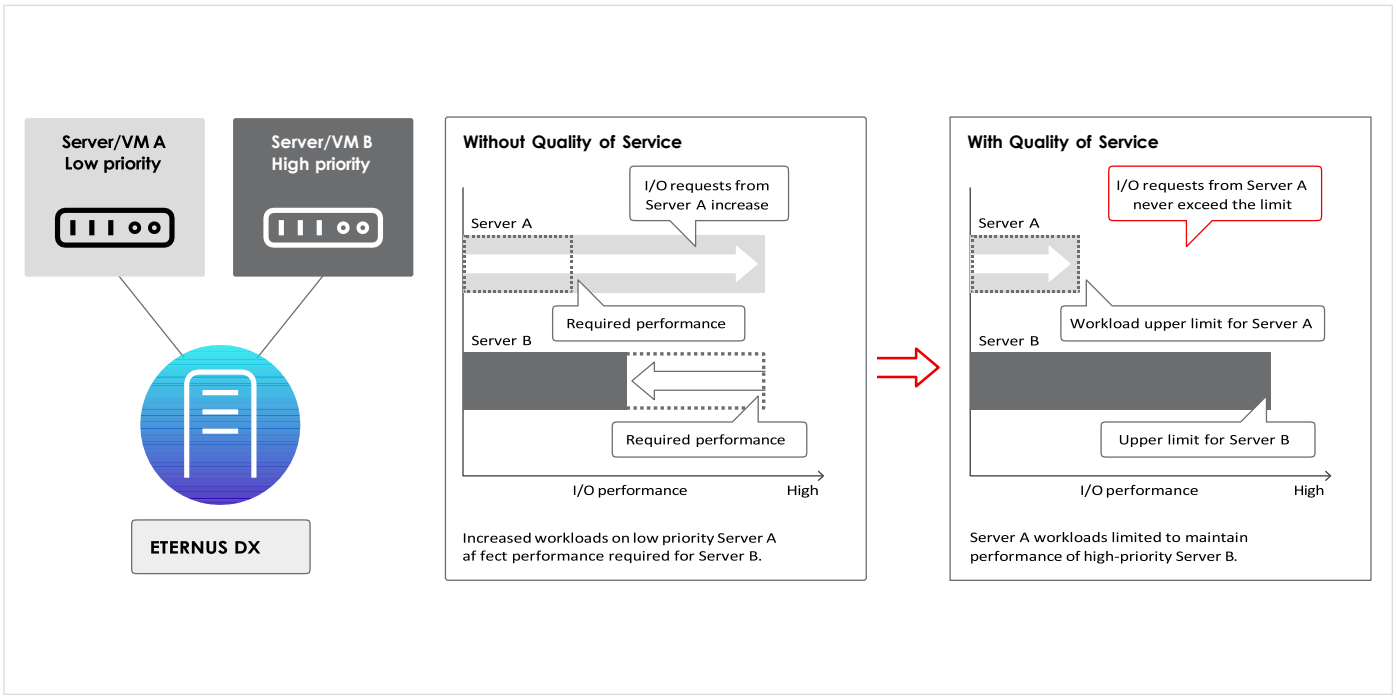
Benefits

- Mapping application Service Level Agreements (SLA) to storage infrastructure
- Increased storage utilization by combining different workload profiles
- Allows service providers to guarantee a specific QoS and charge accordingly

The ETERNUS DX Quality of Service feature with application I/O prioritization resolves these issues and enables the consolidation of multiple tiers of applications in a single storage system.

It sets performance limits for each connected server according to its priority. By prioritizing data access and dynamically managing any I/O conflict, high performance can be guaranteed for high-priority applications, and at the same time capacity is used more efficiently, thus increasing storage utilization without sacrificing performance. The QoS policies allow the user to specify the expected I/O patterns of each application (random, sequential, read or write-based and mixed).

An example is shown in the figure below. Two servers are connected to an ETERNUS DX storage system. Server B is granted a higher priority than server A. Accordingly, limits for I/O requests from both servers are set and server B has a higher limit than server A. In the event of increased workloads on the low-priority server A, the system limits the I/O performance at the predefined level and the performance of the high-priority server B is not affected. Thus, the required I/O performance is guaranteed regardless of the workloads on other servers with lower priority.

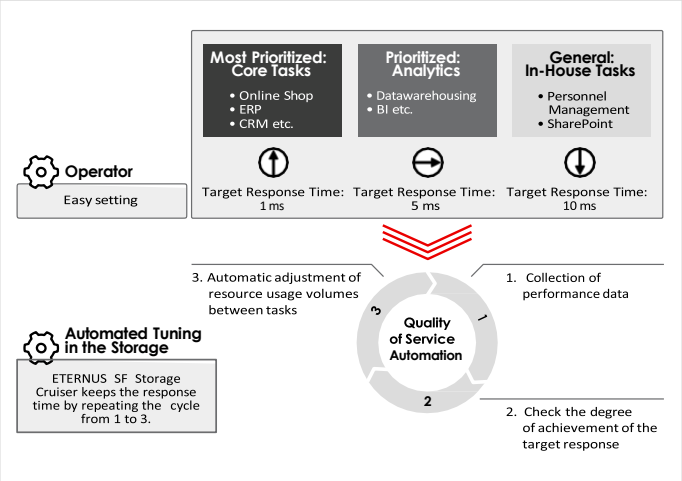


Automated Quality of Service

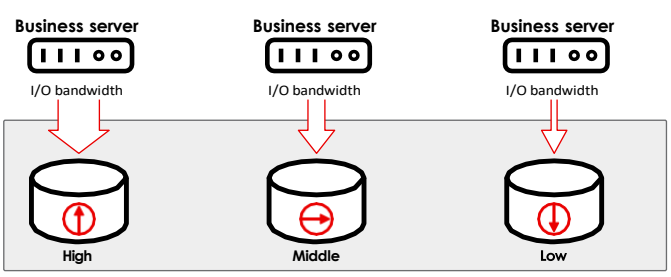
The array-based Quality of Service option as described just limits the IOPS for specific volumes in a static way and requires a lot of expertise and continuous tuning to find the optimum settings. To ease these tasks, the ETERNUS SF automated Quality of Service management option (Automated QoS) lets administrators set values based on performance requirements much more easily and then dynamically adjusts the values along with the result of continuous performance monitoring.

This feature makes it easier for the user to start the settings. Further- more, the automatic tuning ensures that the values used are more accurate, resulting in better service level fulfillment.

Automated QoS gives administrator the possibility of setting predefined target response times.



The setting of a target response time for a given volume is simpler than calculating the IOPS level but it can still be overwhelming for users that do not have a complete view of their environment activity. As an alternative, ETERNUS SF also allows to choose for each volume a level of service making the configuration even simpler. By specifying “Low”, “Middle”, or “High” to the volume ETERNUS SF will share the available storage I/O bandwidth automatically based on those settings.



Configuration of Automated QoS	
Automated QoS Enable/Disable	● Enable ○ Disable
Automated QoS Priority	● Not Set ● Low ● Middle ● High ● Unlimited
⊤ Advanced Configuration of Automated QoS	
Target Response Time	♦ msec

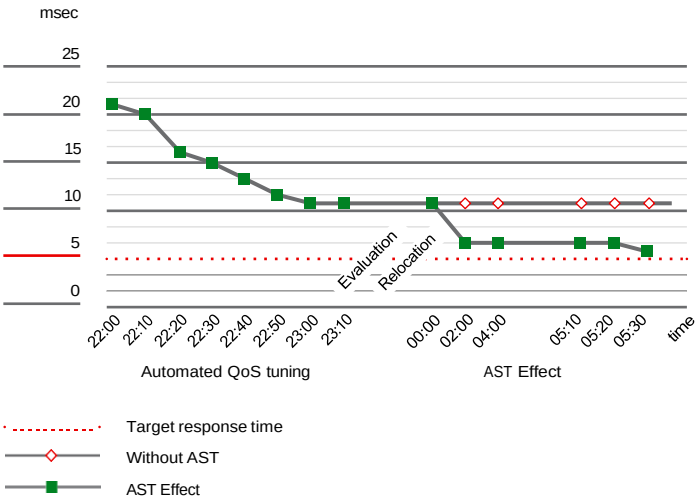
Benefits

- Provides stable storage performance by tuning response time based on a policy of business’ priorities
- Easy adjustments when priorities change
- Flexible in terms of setting response times or priority classes

According to the set response times or priorities Automated QoS limits the bandwidth of volumes of lower priorities enabling the volumes of higher priorities to use a greater bandwidth and so incrementally brings the actual measured values closer to the target response times.

Automated QoS and Automated Tiering

By integrating Automated QoS and AST, ETERNUS SF provides an efficient and automated method to get the best possible performance out of the ETERNUS storage for the user’s business applications.



For more details refer to the whitepaper:
ETERNUS DX – Optimization Features: Automated Storage Tiering and Automated Quality of Service

ETERNUS DX – Automated QoS and Deduplication/ Compression

All-Flash storage for different types of applications brings new challenges. Amongst others, data reduction technologies do not suit all data types – some are already compressed, for example. In addition, turning on data reduction inherently adds a degree of latency back to the storage, which may be a bad idea if absolute performance is key.

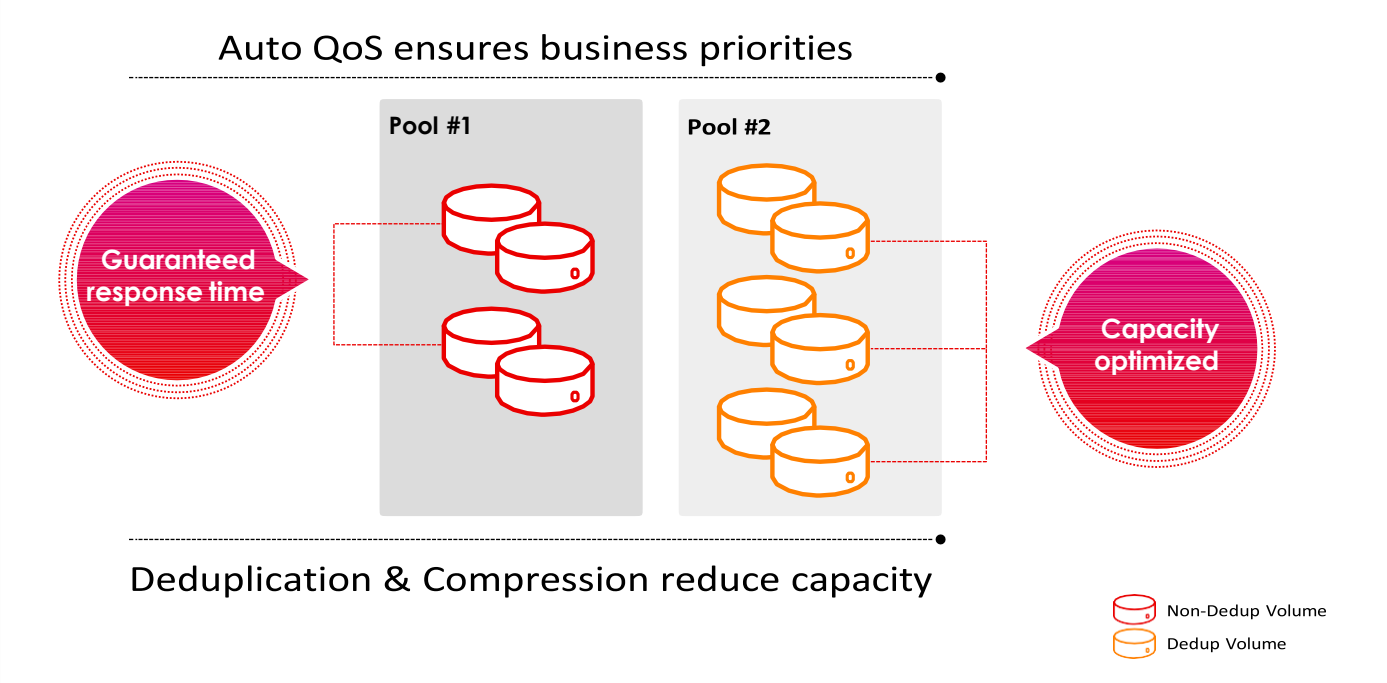
ETERNUS DX consequently provide a clever combination of Automated QoS Pools and Deduplication/ Compression Pools to balance performance and cost in a single system:

- Guarantee response times for every application with Automated QoS by setting predefined target response times.
- Flexible configure Deduplication/Compression by switching it on to optimize capacity on volumes, or keeping it off to meet performance SLAs.

For example, volumes with the Deduplication/Compression function disabled can be used for business server data areas that require fast access speed, and enabled volumes for business server system areas that require storage efficiency. Thus, the same storage system can provide both performance and storage efficiency.

Benefits

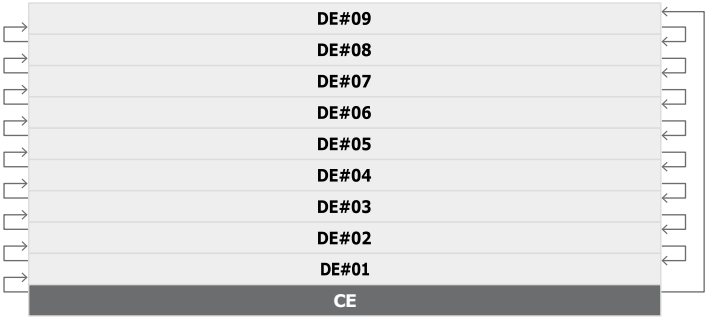
- Combination of Automated QoS and Deduplication/ Compression makes it easy to balance performance and cost
- Ensures compliance with defined SLAs for specific applications
- Simplifies performance management
- Increases storage efficiency significantly



Availability Management

Reverse Cabling

In order to provide high availability, the controller enclosure is connected to the drive enclosure via reverse cabling. The connection of one path is implemented in ascending order while the other path is connected in descending order, as shown in the figure on the right. In the event of a DE failure, only the affected DE is disconnected. All other DEs remain accessible. This pattern further compliments a RAID design in which each member disk of a RAID group is put on a different shelf. In the unlikely event of shelf outage, data still remains intact and accessible.



RAID: Improving Performance and Preventing Data Loss

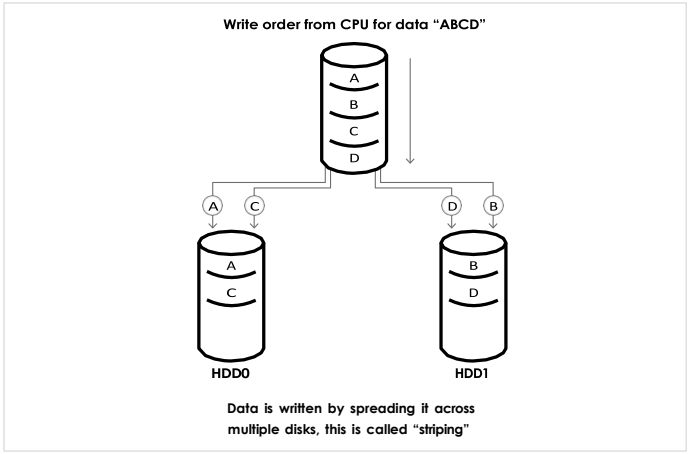
Damage to a company caused by disk failure is a steadily growing risk, as data volumes and disk capacities increase. Storage system downtime can result in companies failing to take full advantage of business opportunities, due to the management overheads involved in securing important data.

RAID technology not only prevents such data loss, but also enhances business performance.

RAID is the use of multiple disks to manage HDD data using a range of different techniques. These are divided into various levels. They all differ in terms of data deployment and the type of redundancy offered. It has also become popular to mix and match the various RAID level technologies in order to provide more specific cost reductions and performance enhancements. This document only concentrates on the main RAID levels that are widely used.

RAID 0

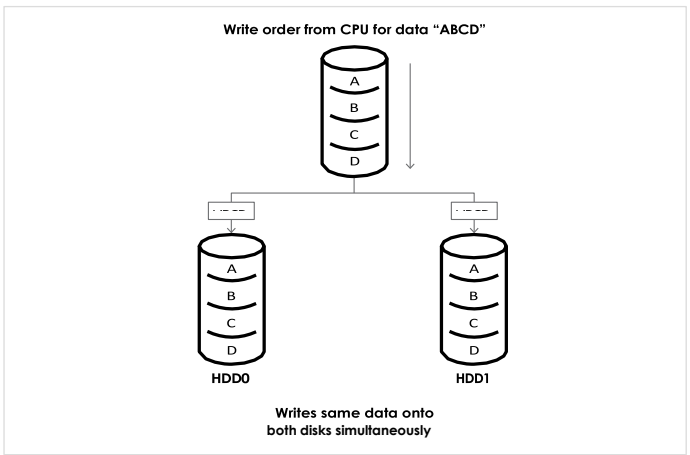
RAID 0 divides data into block units and writes them in a dispersed manner across multiple disks. As data is striped across every disk, this technique is also called “striping.” This process enables high performance, as parallel access to the data on different disks improves the speed of retrieval. However, no recovery feature is provided if a disk failure occurs. If one disk fails, it affects both reads and writes. And as more disks are added to the array, the chance of a disk failure occurrence is higher.



RAID 0

RAID 1

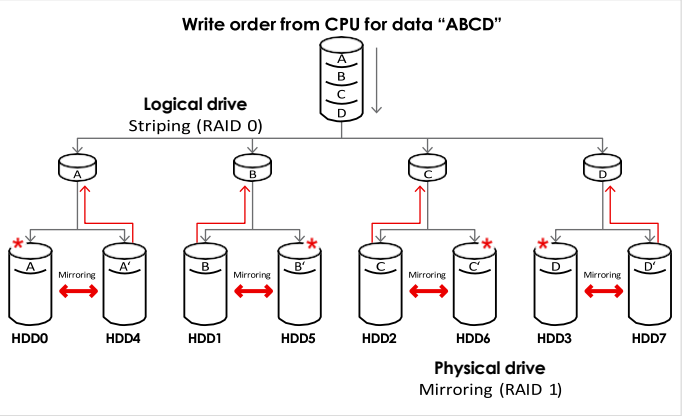
This level is called “mirroring” as it writes the same data to two disk drives simultaneously. Although there is no enhancement in access speeds, the automatic duplication of the data means there is less likelihood of data loss. RAID 1 provides failure tolerance. If one disk fails, the other automatically takes over and continuous operation is maintained. There could be some impact on the overall cost of the disk array because duplicating all the data within the array means that only half of the raw storage capacity is available for the hosts.



RAID 1

RAID 1+0

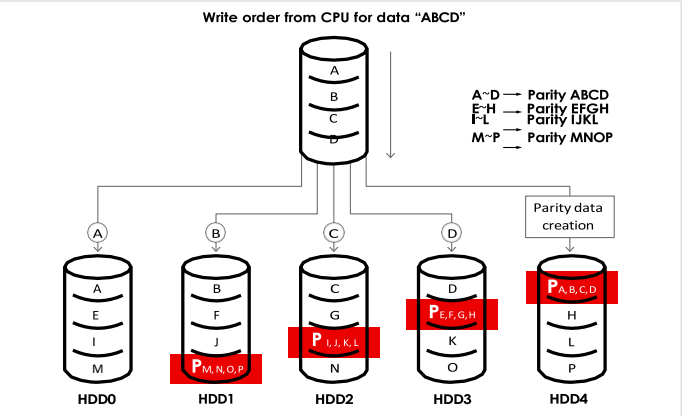
RAID 1+0 combines the benefits of RAID 0 and RAID 1. By configuring both technologies in a single array, both data duplication and improved access speed can be provided. Although this combination makes installation more expensive compared to other technologies. However, both reliability and high I/O performance can be guaranteed. RAID 1+0 on Fujitsu ETERNUS Storage arrays also provides extra protection in those cases where a single drive failure can result in disruption of data access to users.



RAID 1+0

RAID 5

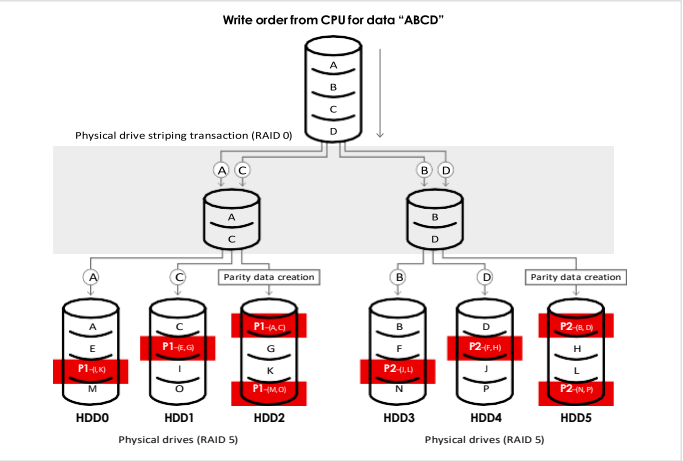
RAID 5 is the most commonly used RAID technology today. It is based on a technique that avoids concentration of I/O on a dedicated parity disk as with RAID 4. RAID 5 divides the data and creates parity information, but the parity data is written separately across multiple disks. It enables multiple write orders to be implemented concurrently because updated parity data is dispersed across the multiple disks. This feature ensures higher performance compared to RAID 4.



RAID 5

RAID 5+0

RAID 5+0 stripes data across multiple RAID 5 groups using a front-end RAID 0 method. Such multiple RAID 5 striping enables one disk per group to be saved in the event of disk failure. This provides higher reliability in large-capacity configuration systems compared to a single RAID5 group. Furthermore, the rebuilding of transactions, which takes an increasingly longer time as disk capacity grows, can be executed much faster with RAID5+0 as the amount of data in each RAID group is smaller.



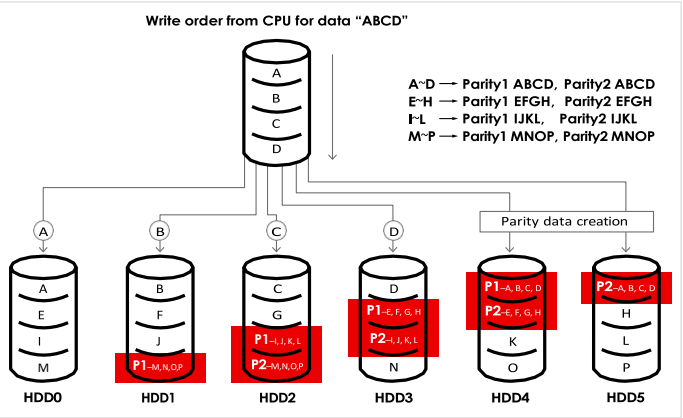
RAID 5+0

RAID 6

RAID 6 deploys two parity records to different disk drives (double parity), enabling two simultaneous disk drive failures in the same RAID group to be recovered. It is thus able to execute multiple write orders at the same time. This feature ensures higher performance. Furthermore, the ETERNUS DX systems are able to deploy disk drives where RAID 6 and 5 arrays are deployed across separate drive enclosures (DE) for improved reliability. Especially for Nearline SAS, high-capacity drives, RAID 6 (with double parity) should always be considered as first choice.

The following table summarizes the different RAID groups and highlights their main benefits:

	Reliability	Data efficiency	Write performance
RAID 1	Good	OK	Good
RAID 1+0	Good	OK	Very good
RAID 5	Good	Good	Good
RAID 5+0	Good	Good	Good
RAID 6	Very good	Good	Good



RAID 6

ETERNUS DX Enterprise Systems: Advanced RAID Organization

Depending on the RAID level each disk drive of a RAID group is located in a different drive enclosure. Spreading the disks drives of a RAID group to more enclosure increases redundancy resp. availability. RAID groups remain accessible even if one complete drive enclosure became inaccessible. Furthermore, with support of RAID 6 (double parity), two disk drive failures occurring in the same RAID group could be recovered. This ensures exceptional reliability.

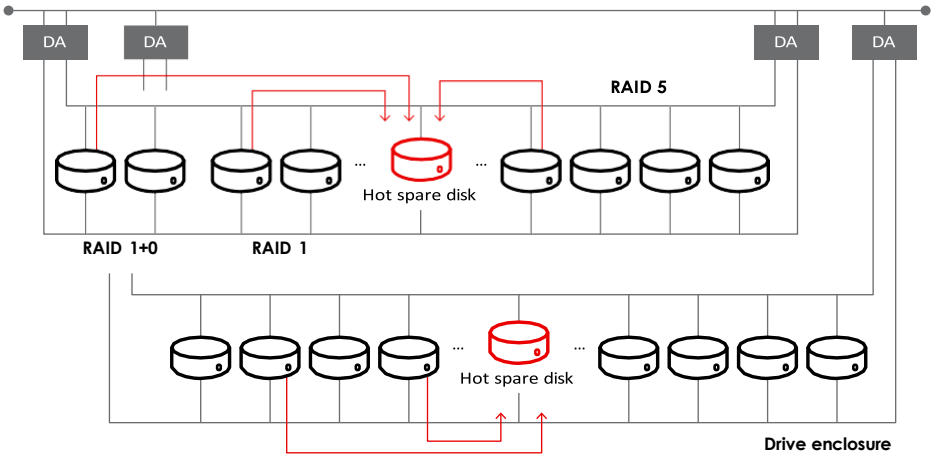
It is recommended to apply this policy for entry and midrange systems, too. Distributing disk drives of the same RAID group to shelves connected to some same controller enclosure of an enterprise system reduces access time while spreading them across multiple controller enclosures increases redundancy.

Redundant Copy

The redundant copy function enables preventive disk replacement while ensuring data redundancy. When a disk is diagnosed for preventive replacement, this function recovers data using other disks in the same RAID group and writes that data to a hot spare. Once the write is complete, the hot spare takes over and the disk at fault is detached. ETERNUS DX online storage systems support two hot-spare types: global hot spare and dedicated hot spare.

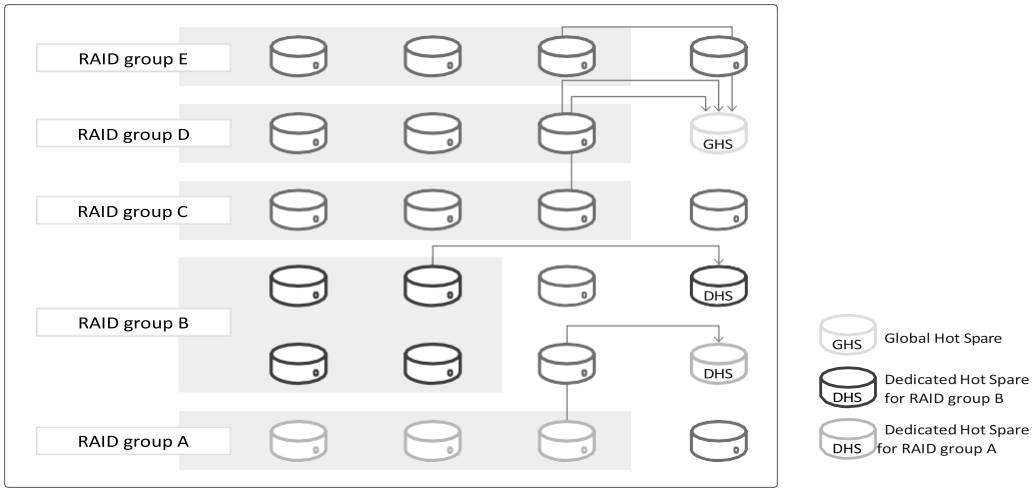
Global Hot Spare

Hot spare disks are preparatory disk drives that are kept on active standby for use when a disk drive fails. This global hot spare function enables hot spare disks to be used for any RAID group. When a disk drive in a RAID group fails, data on the disk drive is automatically reconstructed on the hot spare disk in background.



Dedicated Hot Spare

Unlike global hot spare disks, which can be used with any RAID groups, dedicated hot spare disks can only be used with a specific RAID group. When a disk drive fails in the RAID group which has a dedicated hot spare, data on the disk drive is automatically reconstructed on the dedicated hot spare disk. A dedicated hot spare is a special case of a global hot spare for use in dedicated mission-critical environments where sharing does not offer sufficient security.



Copy-Back and Copy-Back-Less Operation

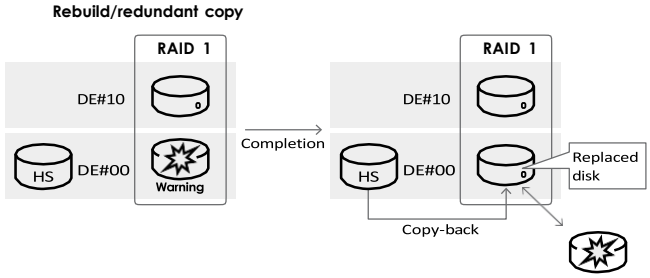
After the faulty disk has been replaced with a new disk, data on the hot spare disk is retrieved (copied back) to the new disk. The copy-back function restores the RAID group while maintaining redundancy after the rebuild has been performed for the hot spare in the RAID group.

Copy-back-less function is a feature which builds hot spare disks into a RAID configuration after the completion of rebuild or redundant copy and the internal RAID configuration of the failed disk is changed to hot spare disk. Immediately after maintenance and replacement, it can start working as a hot spare disk. This feature means that the copy-back process is no longer required.

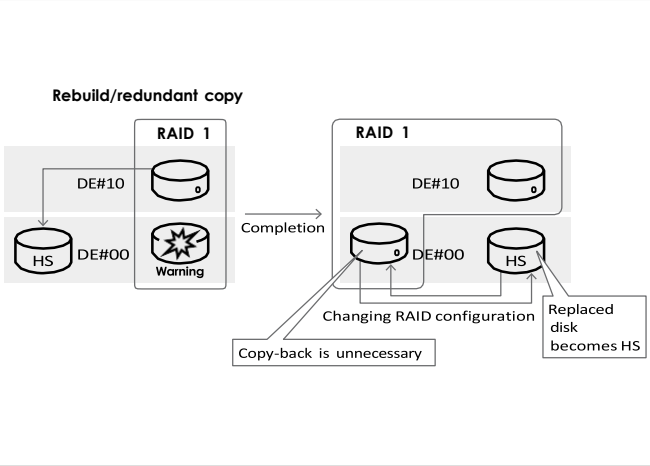
Example: Rebuild: 4 hours, copy-back: 4 hours, disk replacement: 0.5 hours

	Working time for replacement of disk	Time until HS becomes available
Copy-back	**Max 8.5 hours** (Rebuild+Replacing Disk+Copyback)	**8.5 hours** (Rebuild+Replacing Disk+Copyback)
Copy-back-less	**Max 4.5 hours** (Rebuild+Replacing Disk)	**4.5 hours** (Rebuild+Replacing Disk)

The administrator can choose between copy-back and copy-back-less operation via the GUI.



Copy-back



Copy-back-less

Benefits

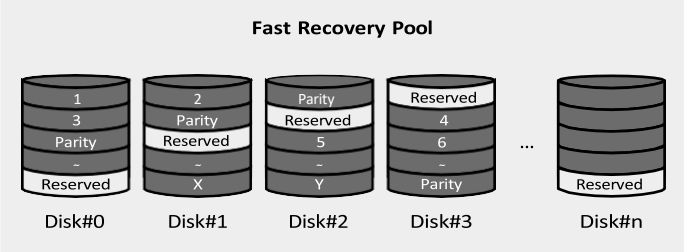
- Disk replacement time is drastically reduced
- RAID availability is improved as the hot spare downtime is reduced
- I/O performance degradation during the copy-back process can be avoided

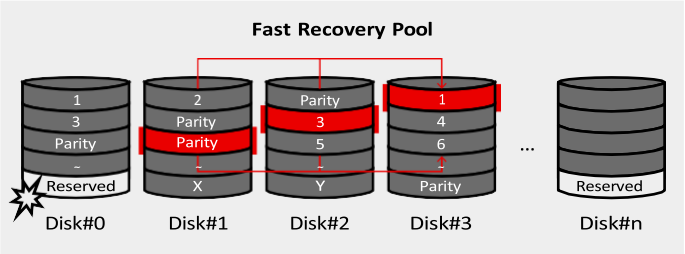
Fast Recovery

Rebuild is a process that restores the contents of the failed disk from the remaining normal disks. If a hot spare disk (HS) is installed after a disk failure, the rebuild process is performed from the hot spare and redundancy is restored.

Fast Recovery is a feature which helps shorten the rebuild time. For Fast Recovery Volumes no exclusive hot spare disk is available, but a reserved area for rebuild is prepared in each disk in the RAID group, as shown in the next figure.

When a disk failure occurs, rebuild on reserved areas in multiple disks is performed simultaneously, unlike the traditional rebuild function where it is carried out disk-by-disk. This reduces the rebuild time for a 1 TB disk to 90 minutes instead of 9 hours with traditional rebuild. Fast Recovery requires copy-back after a disk has been replaced.

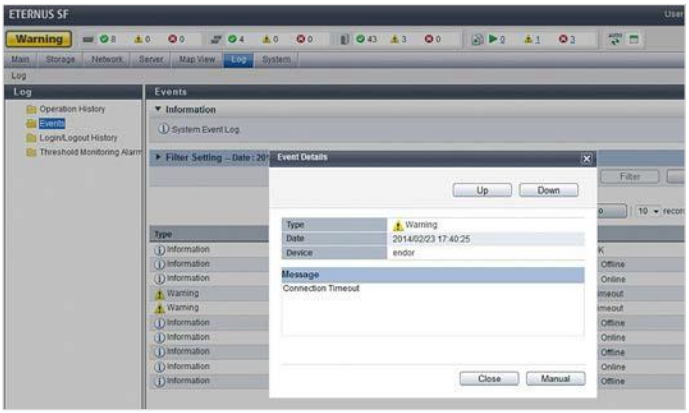


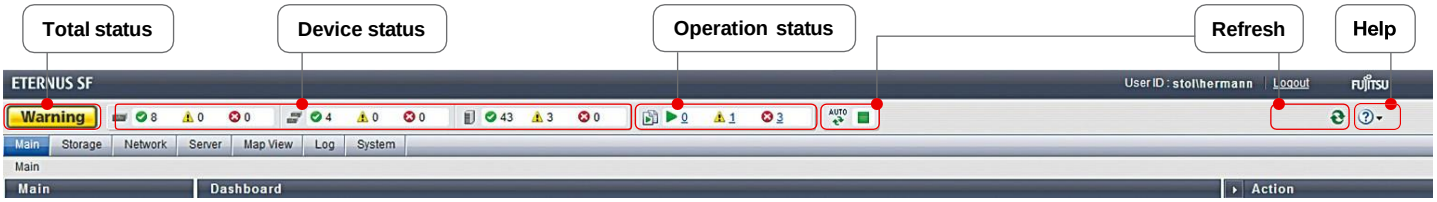


Event Management

The system monitoring and event management of ETERNUS SF, with permanent monitoring for detecting early signs of malfunction, enable immediate corrective actions. A troubleshooting assistant provides explanations of corrective actions.

Event notifications are provided as “Information”, “Warning” or “Error”. They can be forwarded via e-mail. The icon color of a device changes depending on its current status as shown in the picture below. When Remote Support is configured, event notifications are also automatically sent to Fujitsu customer service.



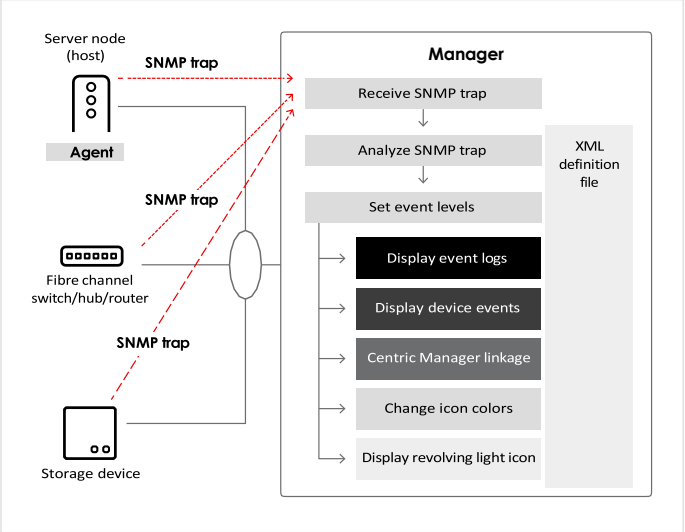


Depending on the capabilities of the devices the event management function itself can be executed manually, via notification of the ETERNUS DX or via external polling devices:

The event monitoring processes SNMP traps, decodes them, and displays them as an asynchronous event. The manager thus supports smooth operations because the displayed contents of the event are more detailed and easier to understand than decodes generated by a normal SNMP MIB compiler.

The customized content and the display format (show, hide) for events can be adapted in detail. Therefore, operation can be flexibly customized for specific operational environment requirements. Integration with various other management software products is also possible.

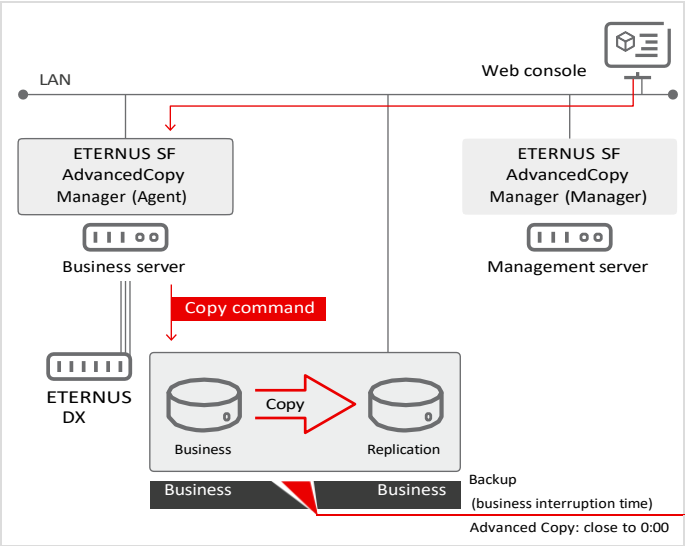
Event monitoring using the device polling function regularly monitors the status of all devices connected via LAN by using SNMP, ping or unique protocol and can also be customized using definition files.



Continuity Management

AdvancedCopy

While data is growing exponentially, its importance is also growing from regulatory compliance and business continuity standpoints. Thus, efficient easy replication and backup of large data volumes is becoming a critical issue.



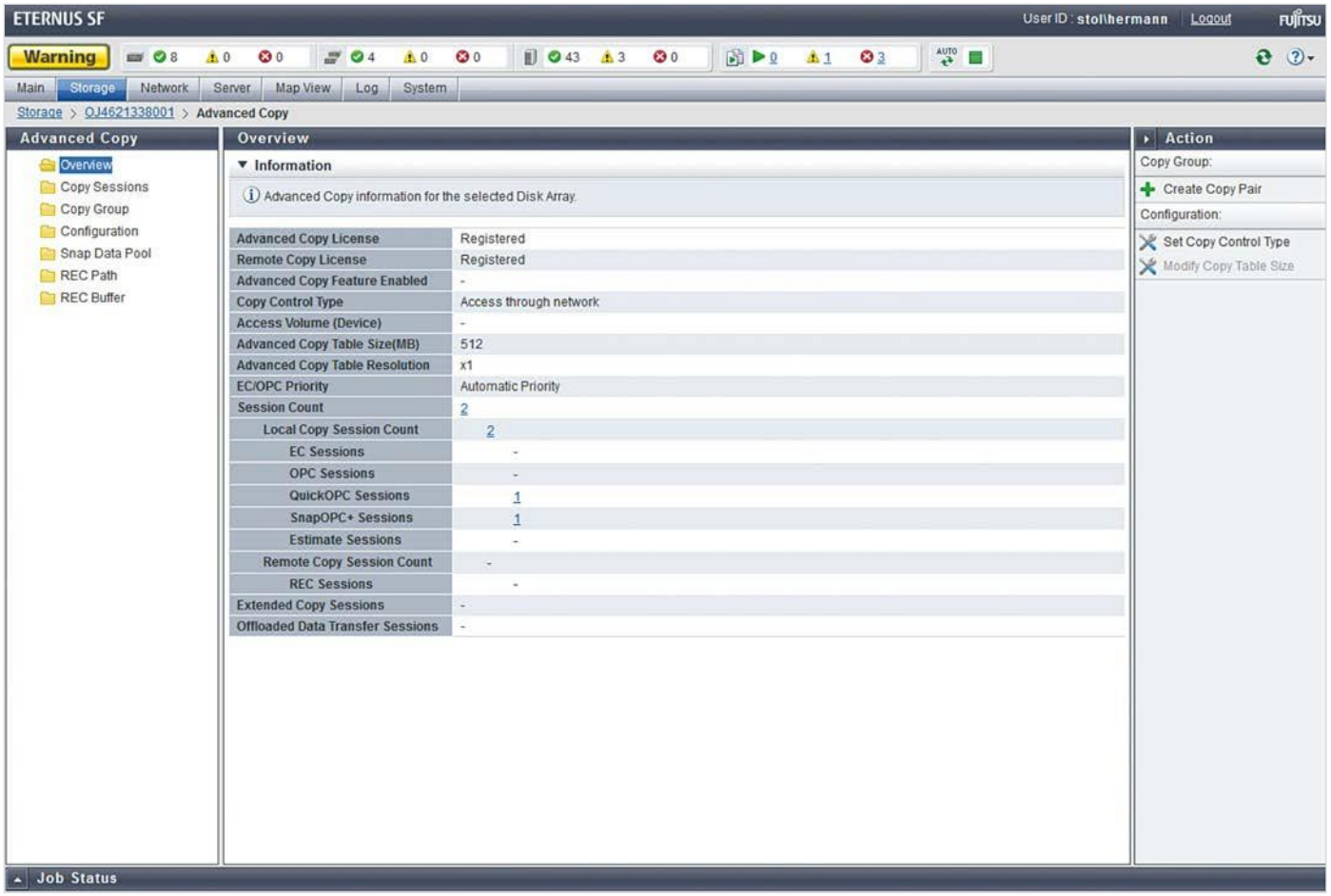
ETERNUS SF, together with the hardware-embedded AdvancedCopy of the ETERNUS DX storage systems, enables high-speed and high-reliability backup/restore and replication operations. To achieve continuous 24 x 7 business continuity, ETERNUS SF takes over all the tasks required for implementing a disaster-resilient storage infrastructure.
Thus, ETERNUS SF significantly reduces operational downtime, especially in large-volume, transaction-intensive environments. The software can be deployed in conjunction with a wide range of mainstream database environments, including Oracle Database, SQL Server, DB2 and Exchange Server, to provide reliable high-speed data copying without going offline and without downtime.

With these capabilities data center managers achieve the following targets:

- High speed backup operation
- Short Backup-Restore time regardless of data volume
- Disaster recovery with remote copy
- Fast recovery of business operations
- Database backup without interruptions or heavy loads
- VMware environment backup/restore
- Hyper-V guest online backup

The embedded AdvancedCopy functions of ETERNUS DX supports the copying of data from a business volume to another volume, both within the same ETERNUS DX storage system and across multiple ETERNUS DX storage systems in the storage network. Remotely located storage systems can be connected to this infrastructure via high-speed technologies. A wide range of replication features are supported for:

- Local volume replication of data
- Synchronous and asynchronous remote data replication
- Transparent failover
- Recovery of host-based data
- Support of various data protection and backup or archiving policies
- Support of data migration to physical and virtual tape libraries
- Support of a rich set of snapshot functionalities
- Support of virtual server environments



AdvancedCopy Functions of ETERNUS DX

ETERNUS DX systems support two distinct data copy modes: Snapshot high-speed copy and synchronous high-speed copy.

Snapshot high-speed copy creates a snapshot of data. The copy types available with this function are:

OPC (One Point Copy)

This **Background Copy** function creates a copy of the business data volume at any point in time. Data on the business volume is copied logically to a copy volume, quickly, as and when required. The copy volume can be used for backup operation to a tape device, while business operations can continue on the business volume.

QuickOPC

This **Background Copy** function creates a copy of all the business data volume, but copies only data that has been updated since the previous update and subsequently only copies updated data. This is suitable for large database operations where backup times must be reduced.

SnapOPC

This **Copy-on-Write** function creates a copy of the data prior to it being updated. As it requires less copy volume capacity when compared with full backup, SnapOPC is ideal for backup operations for systems such as file servers, with relatively few updates.

SnapOPC+

Like SnapOPC, SnapOPC+ is a **Copy-on-Write** function and copies the data only prior to it being updated on the business volume. In addition, SnapOPC+ enables generations management of the updated data. As SnapOPC+ does not actually store duplicate data but manages it as history information (unlike SnapOPC), disk-based generation backup can be achieved using less copy volume capacity.

With these AdvancedCopy functions (with the exception of OPC), once an initial copy has been made, it is possible to perform differential copying, which copies only the modified portions.

Synchronous high-speed copy maintains the equivalent status for a transaction volume and backup volume. The two copy types available are:

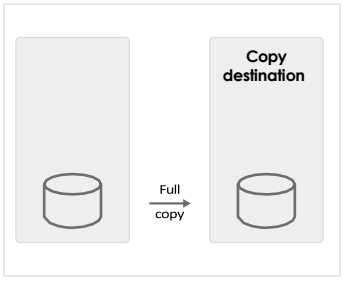
EC (Equivalent Copy)

EC is a mirror/suspend function that always creates a synchronous replication of a business data volume on a copy volume (mirroring within the same ETERNUS DX). The business volume and copy volume are synchronized but can be separated at any required time (mirror suspend). The copy volume can then be backed up to a tape device while business operations continue on the business volume. Suspend/Resume functions can be used to re-establish the mirror by copying only data updated since the mirror was suspended.

REC (Remote Equivalent Copy)

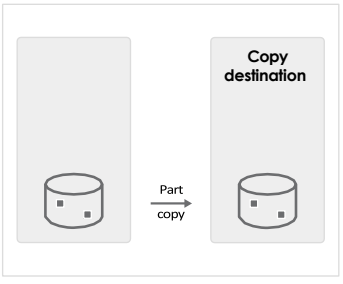
REC performs synchronous high-speed replication from one ETERNUS DX storage system to another ETERNUS DX storage system at campus, metro, or global remote locations.

OPC (One Point Copy)



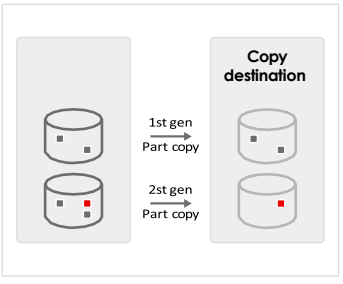
Full copy of the original data (Point in time copy)

QuickOPC



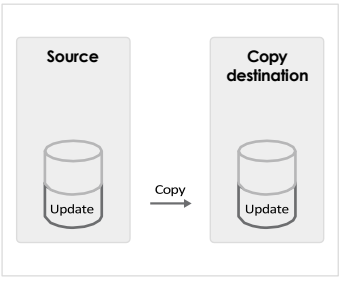
Point in time full copy, then copy of updated data only

SnapOPC+



Copy of updated data only

EC/REC



Full copy of original data, then original data changes automatically reflected to copy destination

AdvancedCopy function	Description
OPC: Clone	Internal function for performing a full copy of the original data.
	Optimized replication and backup operation.
QuickOPC: Clone	Internal function for performing a full copy of the original data once, then copying only updated data subsequently for the further copy operations.
	As backup duration is short, this is optimal for database systems, etc.
SnapOPC+: Snapshot	Internal function for performing a partial copy of original data parts right before they get updated. Only the part to be updated is copied.
	Uses limited disk capacity and allows several backup generations. Optimal for file server backup.
EC: Clone	Internal function for performing a full mirrored replication of data. Optimal for getting a data copy without interfering with heavy load business processing.
REC	Function for performing a full mirrored replication of data between systems. Optimal for backup to a different storage system.

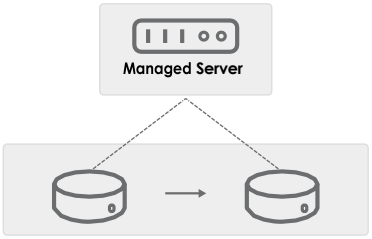
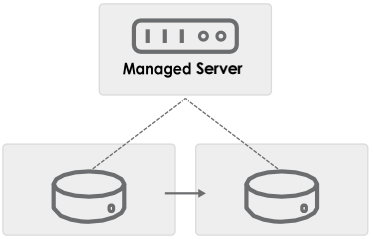
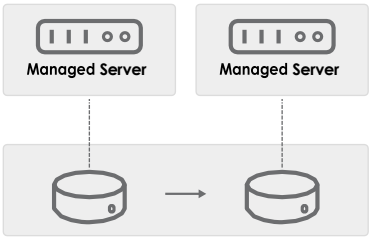
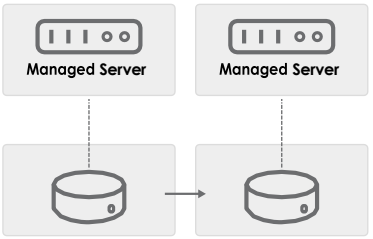
The server-independent snapshot and clone functionality of ETERNUS DX provides simple data protection options with minimal impact on business applications. The snapshot function in particular allows multiple snapshot generations to be stored on a small amount of drive space, while full drive clones can also be generated and managed.

AdvancedCopy with ETERNUS DX has several advantages:

- Backup is performed internally by the ETERNUS DX storage system, minimizing the CPU and I/O usage on the host system.
- Within ETERNUS DX high-speed data copy can be maintained. Remote Equivalent Copy (REC) may require some additional overhead, but the copy is still maintained at very high speed.
- Backups processes using the differential copy capability of the One Point Copy (OPC) and Equivalent Copy (EC) methods run significantly faster.
- The physical copying takes place in the background, in parallel with normal operations.
- Restore processes run at high-speed using the same AdvancedCopy functionality, depending on the backup method originally used.

Usage of AdvancedCopy for Backup or Replication

The following table shows the available data copy modes which can be used for backup or replication:

		Intra-ETERNUS	Inter-ETERNUS
Intra-Server (Managed Server)	Functionality	Backup and replication	Only replication
	Copy Mode	OPC/EC/QuickOPC/SnapOPC/SnapOPC+	REC
	Diagram		
Inter-Server (Managed Servers)	Functionality	Only replication	Only replication
	Copy Mode	OPC/EC/QuickOPC/SnapOPC/SnapOPC+	REC
	Diagram		

Backup/Restore Management Functions

Backup/restore management functions support maintaining multiple generations of the copied data. When restoring data, any one of the backup generations can be selected. Backup management functions deliver storage configuration management for the configurations of source volumes (to be backed up) and target volumes (where backup data is stored) during copying. Unlike the data copied with the replication function, the data copied with backup cannot be used outside this function. By setting a backup policy, the backup can be performed according to that policy, for example, according to the number of backup storage generations and number of backup interval days. The log data management displays the history of the backed-up generation as a log. The ETERNUS SF Copy Control Module (CCM) for local copy and remote copy administration supports backup/restore functions without agents or the utilization of external backup applications.

Backup can only function within a single ETERNUS DX storage system connected to a single managed server, whereas replication can be performed across multiple managed servers or multiple ETERNUS DX storage systems. Backup does not support data copies to a different ETERNUS DX storage system. The replication function is needed to copy data over to a different ETERNUS DX storage system.

Replication Management Functions

Replication supports using the copy data differently from a backup. As multi-generation data management is not supported, several pairs must be defined for one data source and multiple data destinations. Copying to a different ETERNUS DX storage system, including a remote location, is possible. A replication data source and a destination area are defined as a pair, and data is copied inside this pair.

Replication is an excellent way:

- To use the copied data outside a backup dataset (for example, using the copied data in a business application).
- To copy between volumes connected to different servers
- To copy between volumes residing on different ETERNUS DX storage systems.
- To backup data from Microsoft Exchange Server (the backup and restore function does not support copying data from Microsoft Exchange Server).
- To backup data from a Hyper-V Guest OS (The backup and restore function does not support copying data from Hyper-V Guest OS).

Archiving and Disk-to-Disk Backup Using Nearline-SAS Disk Drives

The use of data and its frequency of use changes over time. This can be roughly divided into “frequently accessed data” and “infrequently accessed data.” Data having a high frequency profile will require immediate retrieval and should be stored on high-performance storage devices. However, storing infrequently accessed data on high-performance storage devices generates unnecessary costs. To meet the growing demand for cost-effective and high-capacity storage for less frequently accessed data, Fujitsu provides high-capacity, high-reliability, low-cost Nearline-SAS disk drive options in its ETERNUS DX storage systems. The combination of SAS Online disk drives and Nearline-SAS disk drives in the same cabinet enables ETERNUS DX storage systems to handle the following scenarios cost-effectively:

Disk-to-Disk Backup

Backup volumes on disks are generally used as both temporary storage and high-speed recovery storage following any unexpected storage event. Low-cost, high-capacity and reliable Nearline-SAS disk drives provide the most appropriate storage space for such activities. ETERNUS DX storage systems are highly accessible and cost-effective backup environments thanks to AdvancedCopy functions. Even more cost-effective space utilization and performance is supported by “QuickOPC.” This function only copies data changed per update, thus minimizing the time required for copying.

Long-Term Storage of Reference Data

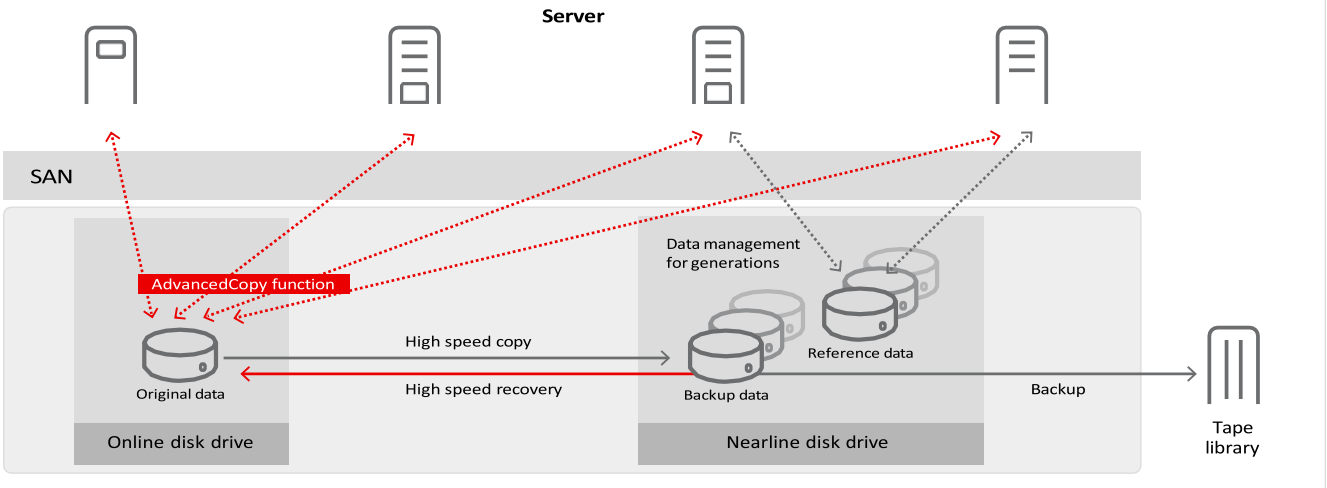
The data in e-mail archives, image and sound files, CAD, R & D documents, and in history or regulatory compliance documents, is subject to the same requirement: It needs to be retrieved easily on demand, despite having an infrequent access profile. This data is growing rapidly and also requires long-term retention. So, when it comes to selecting the right storage medium, low-cost and high-capacity Nearline-SAS disk drives are a good choice.

Disk-to-Disk-to-Tape Integrated Backup

The AdvancedCopy functions enable the disk storage system to carry out high-speed copying operations itself, with no need to draw on server CPU resources. With AdvancedCopy functions, a business data volume can be copied to a separate copy volume, quickly at any point in time, and within the disk storage system. Once the copy is complete, the copy volume can be separated from the business volume, ensuring that no further business volume updates are carried out for the copy volume. Thus, the copy volume data can be backed up to an additional tape device, as a point in time copy of the business data, while normal operations continue. ETERNUS SF in conjunction with the AdvancedCopy of ETERNUS DX and external tape backup software enables disk-to-disk-to-tape backup as a single consolidated operation by linking up the disk-to-disk and disk-to-tape backup processes. This consolidation of resource management and backup destinations also prevents backup/restore operation failures that can occur with less automated processes. In addition, high-speed backup is possible without stopping operations.

Benefits

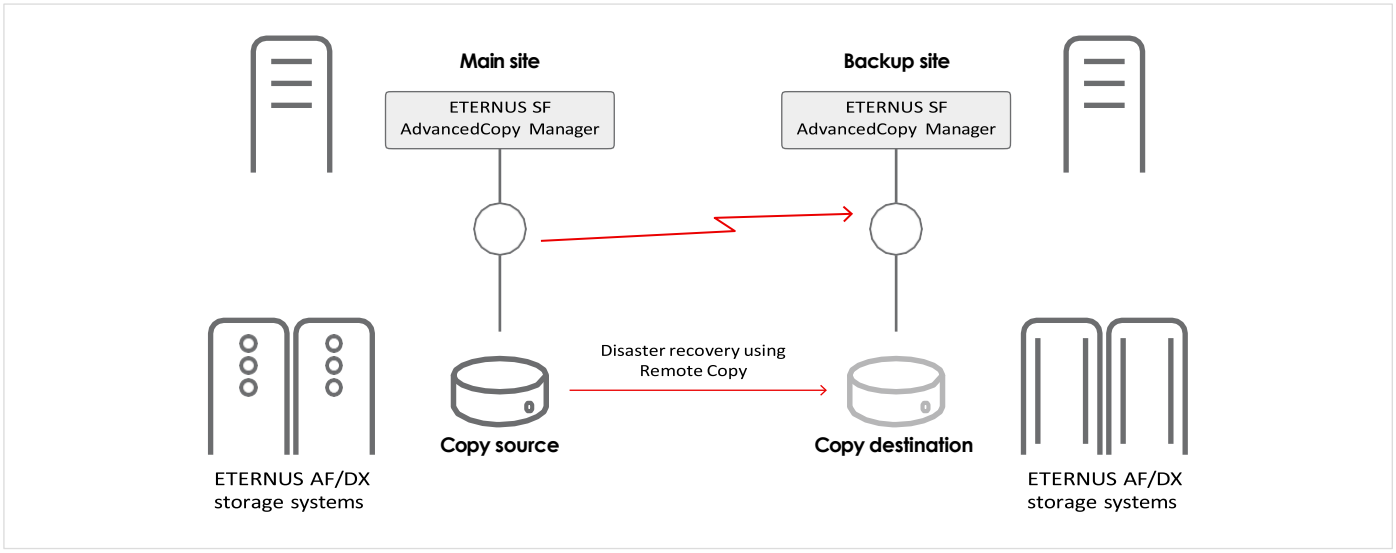
- Tape backup with reduced operation stoppages (with disk-to-disk-to-tape).
- High-speed backup with reduced application server stoppages using the AdvancedCopy function of ETERNUS DX.
- Backup operations put no load on application servers.



ETERNUS DX disk storage systems

Disaster Recovery with Remote Equivalent Copy (REC)

REC provides a server-less remote mirroring function and allows fast recovery if the primary disk storage system site suffers an outage due to a disaster, such as fire, earthquake, flood, etc. ETERNUS SF supports remote copy capability using ETERNUS DX storage systems connected via Fibre Channel or iSCSI interfaces. Secure disaster recovery can be achieved by allocating ETERNUS DX storage systems for backup data storage at earthquake- and other disaster-proof sites. Depending on the required service level and distance both synchronous and asynchronous replication is possible. REC is available over different system classes and multiple generations of ETERNUS AF/DX, thus allowing the most economical and flexible deployments.

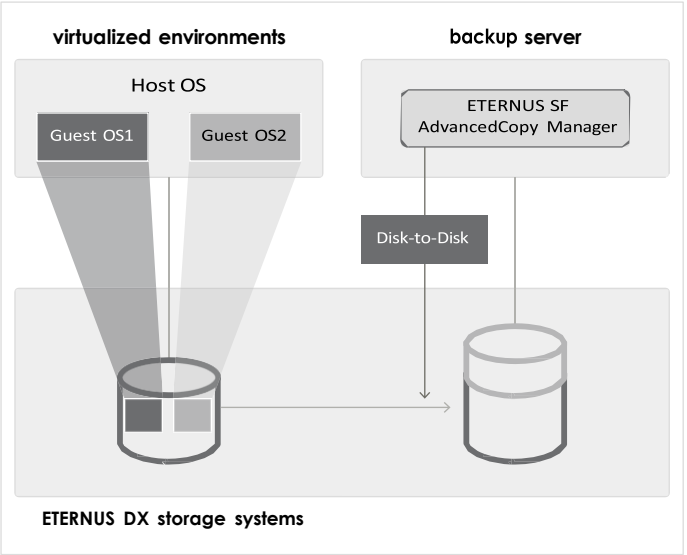


Integrated Backup to Support Physical Environments and Virtualized Environments

In both physical environments and virtualized environments, disk-to-disk backup operations “per LUN” are available to back up resources. They are also applicable to virtual machine resources in a virtualized environment based on Windows Server Hyper-V or VMware VMFS. Since the operation does not need to be changed for each environment, the complexity and rising cost of operations can be kept under control, even when migrating from a physical environment to a virtualized environment.

In addition, with ETERNUS SF performing AdvancedCopy backup operations, the backups can be done without imposing loads or stopping the application server operating system for:

- Hyper-V guest OS via ETERNUS VSS Hardware Provider (VSSHP).
- Database systems in cooperation with Oracle, Fujitsu Software Symfoware, Microsoft SQL Server, DB2 and Microsoft Exchange Server.



Storage Cluster – Transparent Failover

Storage Cluster guarantees business continuity even if a storage array has to face planned or unplanned outages. Storage Cluster can be deployed in Fibre Channel (FC) and iSCSI environments. Thus, organizations can leverage existing skills, because Ethernet is common standard and fast enough for most organizations.

There are two approaches to configure highly available storage architecture:

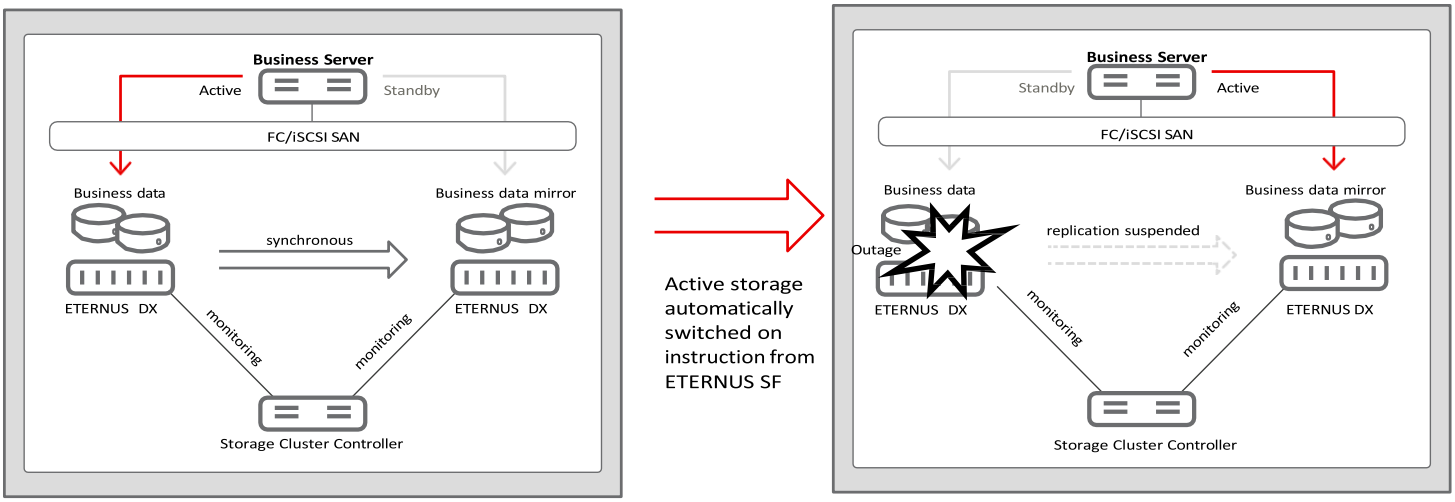
- Active / Standby
- Active / Active

Active / Standby

As long as the primary storage system is running, data is transferred from it to the secondary system via a synchronous replication function. The Storage Cluster Controller continuously checks the status of the primary storage. If a failure is detected, it runs the failover logic, and the primary storage information (e.g., LUN ID/WWN, or with iSCSI: IP addresses/port settings) is shifted over to the secondary storage in order to transparently identify the volume via the server I/O. Hence, operations run smoothly and ensure business continuity.

Due to the restrictions on synchronous mirroring between the storage systems, Storage Cluster can be deployed in building, campus, and metro environments. For regional or global business continuity and disaster recovery scenarios, ETERNUS DX can be deployed with asynchronous remote mirroring functionality resulting in increased RPO and RTO, and without automated and transparent failover.

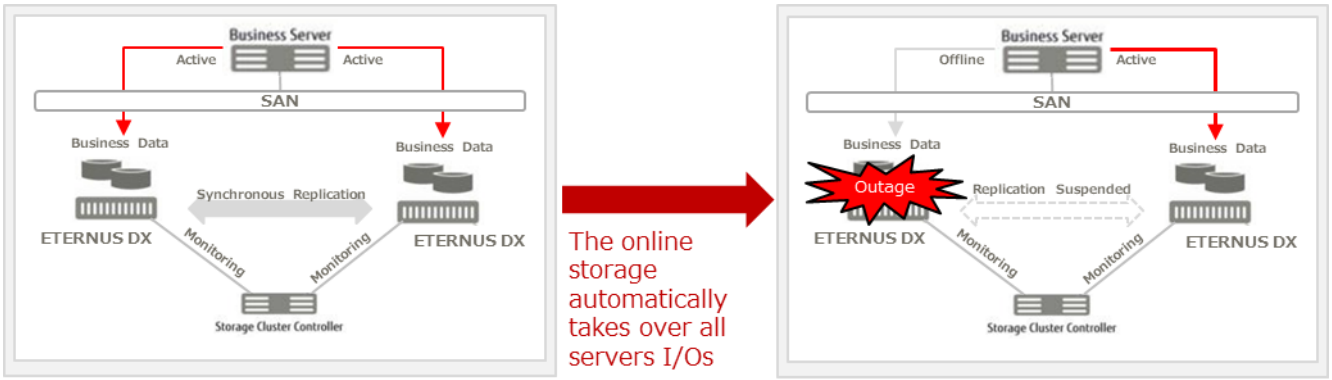
Please note: In environments where iSCSI configurations are used for the host connection and the copy path, switching storage systems for a failover or failback requires approximately 30 to 120 seconds which is more time than for Fibre Channel (FC) configurations. Therefore, unlike FC configurations, a failover might not be performed transparently, and the business server may be aware of the operation. For iSCSI configurations, please refer to "Fujitsu Storage ETERNUS DX – Storage Cluster Function Guide".



Active / Standby

Active / Active

A Storage Cluster operating in an Active-Active manner, functions by synchronously replicating data across multiple geographically dispersed ETERNUS DX S6 systems. This setup ensures that data remains available and consistent even in the event of a site failure. Each site hosts its ETERNUS system, which is continuously mirrored to the counterpart at the other site. In case of a failure at one site, operations seamlessly switch to the alternate site, minimizing downtime and ensuring uninterrupted access to data. Active/Active Storage Cluster provides high availability, disaster recovery capabilities, and load balancing across sites for optimal performance.

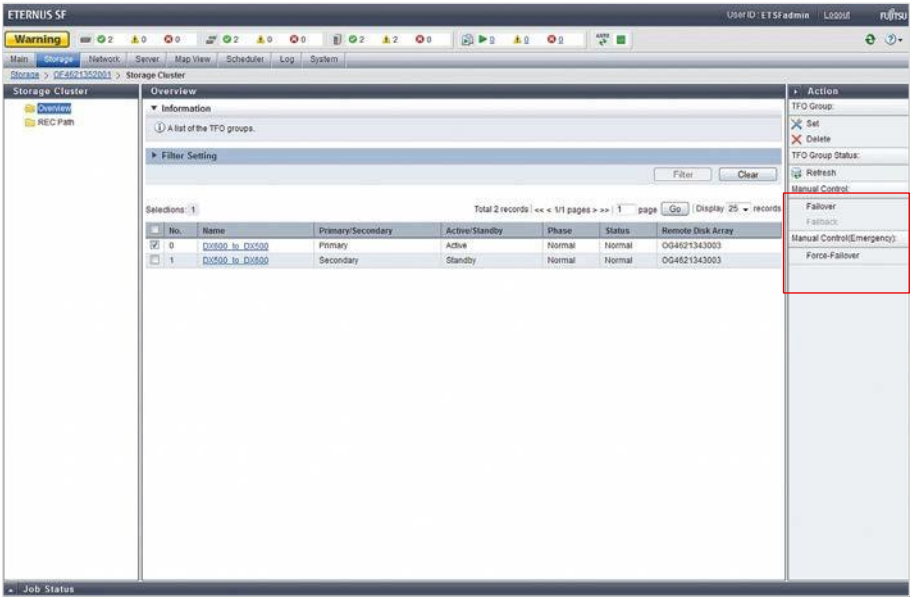


Active / Active

Failover also can be manually executed by the storage administrator, e.g., in case of planned outages.

By consistent mirroring data in real time and switching from one system to the other transparently for the server, the data assets are perfectly protected, and business processes are safe from any interruption.

For more details refer to the whitepaper:
ETERNUS DX Storage Cluster



Information Security Management

Data Confidentiality

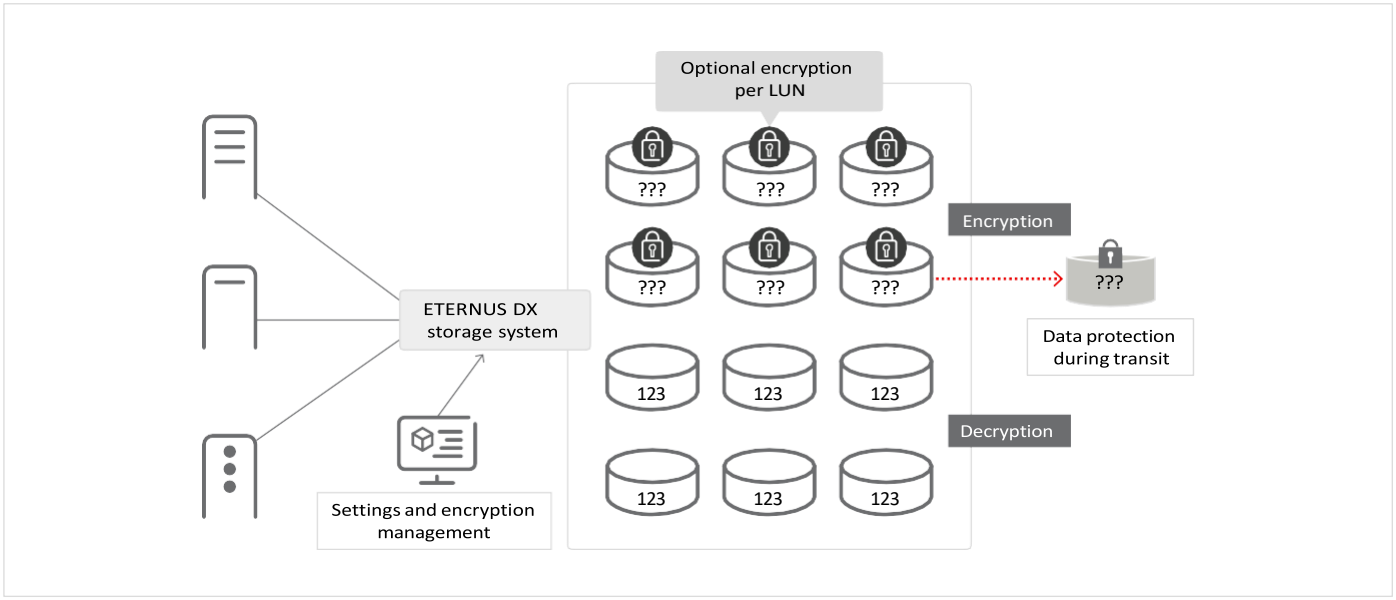
Due to various data protection laws, enterprise information and the security involved has become much more important from a corporate social responsibility standpoint. Laws and internal guidelines require that access to relevant stored data is restricted only to authorized users and that sensitive information is protected against unauthorized or accidental access. ETERNUS DX storage systems provide data encryption functions to address such requirements.

Controller-Based Encryption

Data can be automatically encrypted inside disk storage systems using high-security 256-bit AES technology or Fujitsu Original Encryption. This not only ensures that data is protected during use – it also ensures security during data transfer to off-site archive facilities.

Fujitsu Original Encryption is a unique encryption scheme that encrypts drive data in ETERNUS DX per LUN. It comes at no extra cost and provides some key benefits in comparison with 128-bit AES encryption, such as:

- Less performance degradation
- Closed technology ensuring higher security

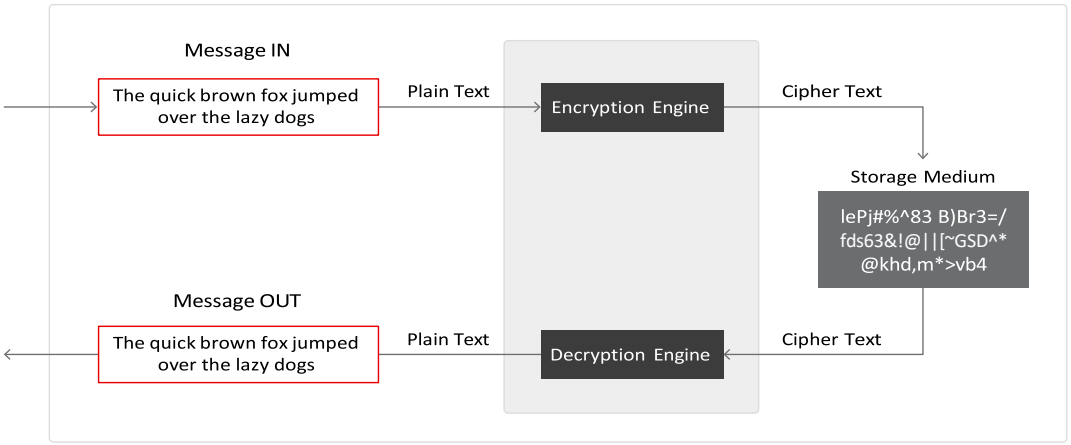


Self-Encrypting Drives (SED)

In order to ensure full data security, the ETERNUS DX architecture supports self-encrypting drives (SED). Self-encryption means that all data transferred to the storage medium is automatically encrypted internally before it is written – and vice versa. When data is read from the storage medium, it is automatically decrypted into plain text. All data passing the interface between the host controller and the disk drives interface is in plain text. The internal encryption process is transparent for the host. All read/write operations for the host are business as usual. The plain text is encrypted (cipher text) when it is written to the disk and decrypted (deciphered) back to the original text when it is read from the disk. SEDs do not affect system performance as the encryption process is not performed by the controller but by the drive itself.

The SED uses two methods for the encryption/decryption process:

- **The internal data encryption key**
  Each SED generates an internal data encryption key in the factory, which is embedded in the drive and cannot be read out or deleted. The encryption key can be modified to destroy or delete the data.
- **The algorithm of the encryption/decryption engine**
  The algorithm is a standard known as the Advanced Encryption Standard (AES), which is recommended by the US government. There are two versions of this standard: AES-128 and AES-256. The numbers 128 and 256 refer to the bit size of the encryption key used by the algorithm. ETERNUS DX storage systems support FIPS-certified self-encrypting drives.



Robust Security Using SSL/SSH

The ETERNUS DX series supports SSL (Secure Socket Layer)/SSH (Secure Shell) for encryption and secure transfer of data over a network. Normal data transfer without encryption bears the risk of possible unauthorized accesses from malicious web browsers and CLI that appear authorized yet are attempting to steal or manipulate data.

SSL enables a secure transfer of important data using SSL server certification (public key and secret key) on both the browser and web servers. SSH encrypts data using common key encryption mechanisms (DES, AES) when it is forwarded from one computer to another via a TCP/IP network. SSH achieves high data security by also hiding the common key using public key encryption mechanisms. Encrypted communication between ETERNUS DX systems and user terminals equipped with these technologies prevents the manipulation and theft of important information.

One-Time Password

In case of a forgotten password, the Fujitsu support department can provide a system-specific password that automatically expires after a defined time.

RADIUS

Remote Authentication Dial-In User Service (RADIUS) is a networking protocol that provides centralized Authentication, Authorization, and Accounting (AAA or Triple A) management for users who connect and use a network service. RADIUS is supported by ETERNUS Web GUI and the ETERNUS CLI as well as for connections to the ETERNUS DX through a LAN using operation management software.

An authentication request is sent to the RADIUS authentication server outside the ETERNUS system network. The authentication method can be selected from CHAP and PAP. Two RADIUS authentication servers (the primary server and the secondary server) can be connected to balance user account information and create a redundant configuration.

Data Integrity

Data errors can occur for different reasons. They result in data corruption, which in turn can lead to a loss of important business information. The ETERNUS DX storage systems support the following techniques which ensure data integrity:

Data Block Guard

The Data Block Guard function adds check codes for data stored during write operations. While verifying the codes for the read/write operations, it guarantees data integrity at multiple checkpoints along the data transmission route.

Oracle Database Data Guard

While Data Block Guard is very important, it still does not cover those situations where data corruption occurs in the interfaces between systems. It only verifies data after it has reached the storage device.

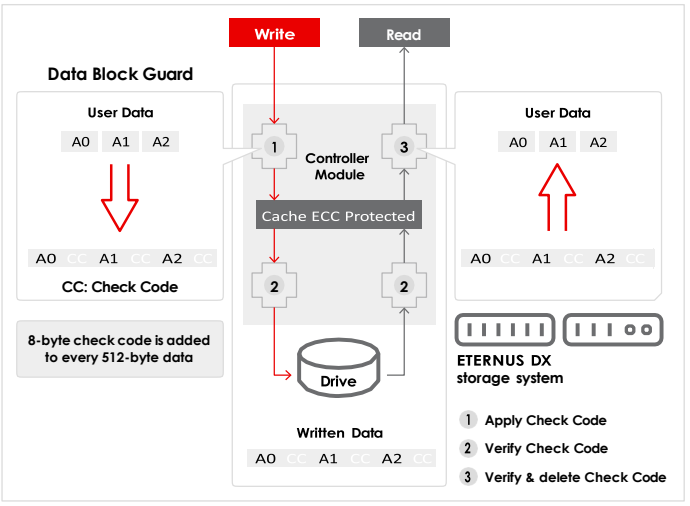
Fujitsu also uses another data protection mechanism called Database Data Guard by Oracle. This combination of data security measures enables ETERNUS DX storage systems to provide very robust data integrity.

With Oracle Database Data Guard, Fujitsu ETERNUS DX Storage arrays provide a comprehensive set of services that create, maintain, manage, and monitor one or more standby databases to enable production Oracle databases to survive disasters and data corruption. Data Guard can be used with traditional backup, restoration, and cluster techniques to provide a high level of data protection and data availability.

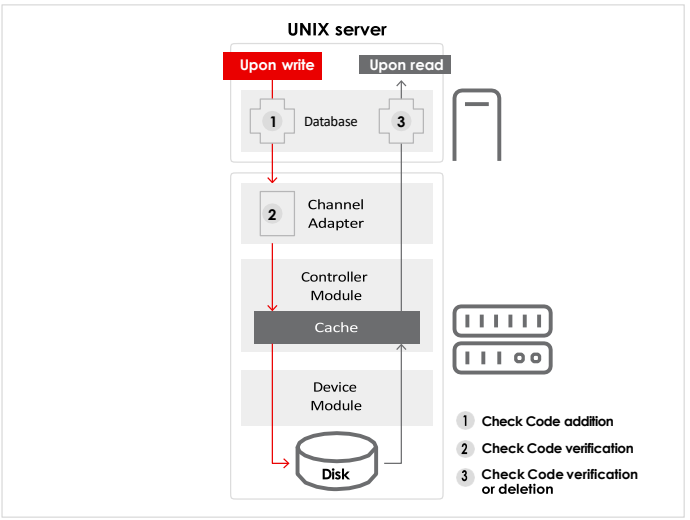
Disk Drive Patrol

Data on the ETERNUS DX storage systems is protected via a disk drive patrol function. The controller regularly checks the disk drives in order to detect errors and write failures. This process also ensures data consistency within the volume group.

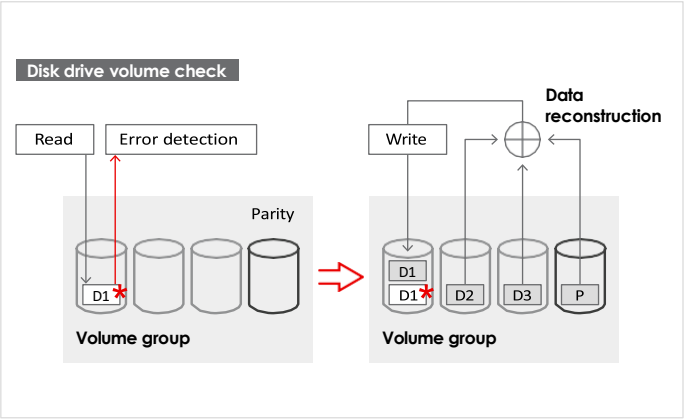
Data on each disk drive is read, and if corrupted data is reconstructed via the redundant information contained within the volume group. The corrected data is then written to a new valid area on the disk drive.



Data Block Guard



Database Data Guard



Disk drive patrol

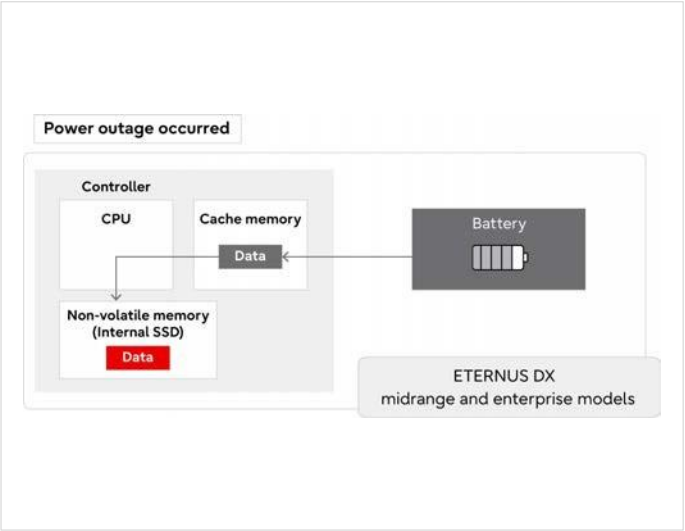
Benefit

- Higher data reliability as data errors are quickly found and corrected (by reconstruction) and disk write failures are avoided.

Cache Guard

The use of a super capacitor as a power supply is suitable for the entry-level. The ETERNUS DX midrange and high-end models, due to their high amounts of data, require batteries to power the mechanism.

Redundantly configured batteries inside the ETERNUS DX storage systems allow data in cache memory to be moved to non-volatile memory or to physical disk drives in the event of a power failure. This secured data can then be maintained in that state indefinitely.



Storage Migration

When a storage system is replaced, storage migration allows logical volume data to be moved from an older ETERNUS DX/AF Storage array to a newer ETERNUS DX Storage array without involving the host. In this process, the new ETERNUS DX storage system (migration destination) connects directly to the existing storage system (migration source) in order to copy the data in the logical volume on a block level basis. No additional software or licenses are needed for the storage migration.

Data migration can be conducted in two ways:
Offline data migration: In this case access from the host is suspended when data is being copied during this process. This data will remain inaccessible during data migration. However, there are cases where server shutdown or disruption to applications is not an option, and this is where non-disruptive data migration comes into play.

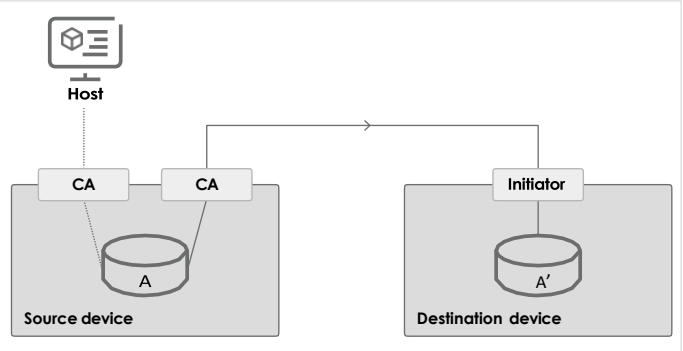
Non-disruptive data migration: In this case data remains accessible during data migration. Disruption of any kind can only occur at one point where the new path to the migration destination device is mapped to the hosts.

Storage migration can be performed just by changing the operating mode of the migration destination channel adapter (CA) port from normal CA mode to initiator mode. The destination can thus obtain data from the source. The path between the migration destination and source can be direct or via a switch. Path redundancy is also supported to ensure higher reliability. The progress of data migration can be monitored from the GUI. Control functions, such as pause, suspension, and resume, are also available.

Compare functions exist to verify that the data migration has been completed without any errors:

- **Quick compare:**
  compares only several data blocks from the top of a volume
- **Full compare:**
  compares all data blocks in a volume

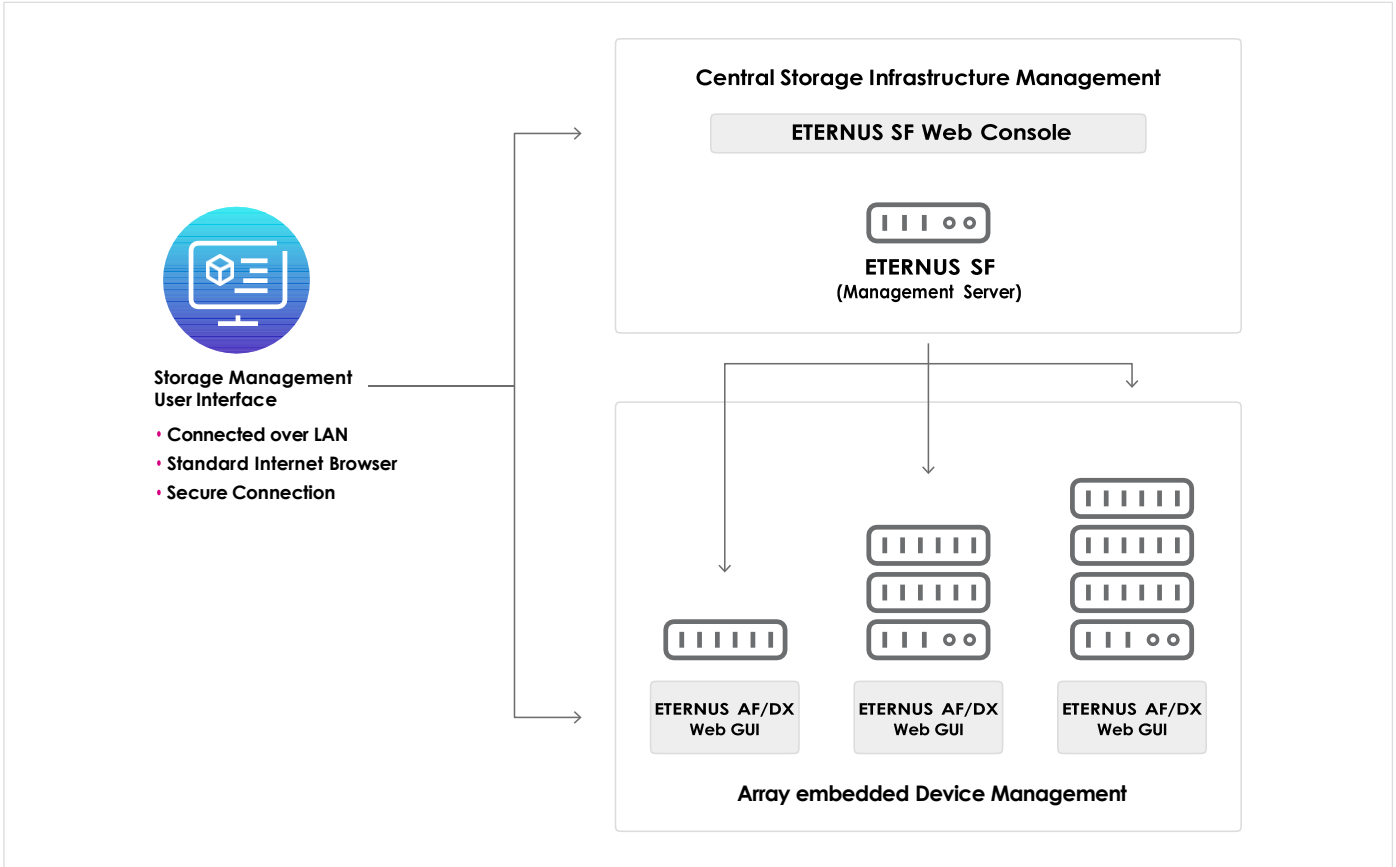
Having completed the data migration process, the operating mode of the destination CA can be changed back to CA mode, and the host is connected to the new storage system.



Efficient & Flexible Management for Business-Centric Storage

The comprehensive flexible data management for Fujitsu Storage ETERNUS DX systems is comprised of convenient, consistent, and powerful tools with enterprise class functionalities. Innovative advanced functions increase the operational efficiency for implementation and control of different service levels. For initial settings, an integrated ETERNUS DX hardware storage management is provided within each individual storage system itself. The additional Fujitsu Storage ETERNUS SF storage management software is used to support overall daily operations within the entire storage infrastructure.

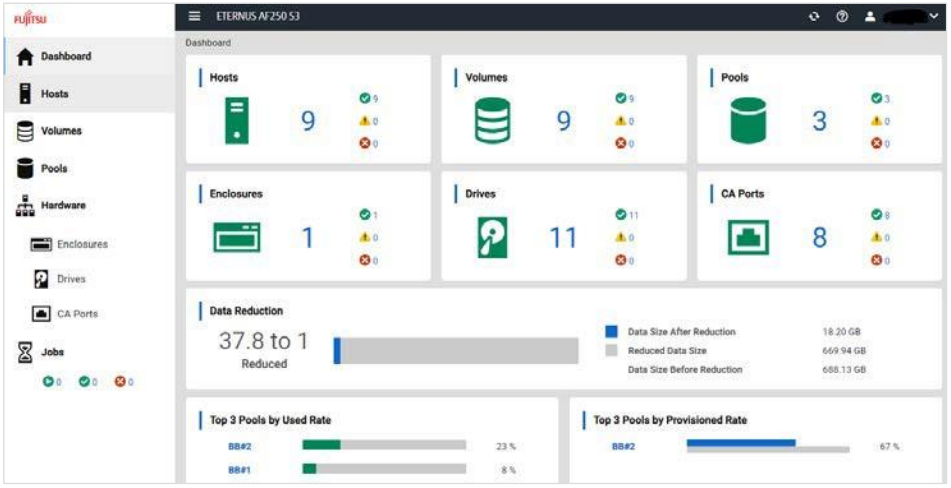
ETERNUS DX embedded management, together with ETERNUS SF, serve as the overarching basis for Fujitsu's highly efficient flexible data management. The aligned unified integration of all commands and data repositories within the ETERNUS DX browser based graphical user interface (Web GUI) and the ETERNUS SF web console offers storage administrators the same usability for all operational workflows throughout the ETERNUS DX series, from entry-level systems up to the high-end models.



ETERNUS DX Web GUI

The Web GUI improves the intuitive operability for initial settings. It is embedded into the operating system and provided by the controllers of the ETERNUS DX series hardware. The Web GUI can be accessed from a web browser by connecting the PC via LAN connection to the storage system. The overview screen appears immediately after logging into the Web GUI. The status of the disk storage system, the usage of RAID groups, Thin Provisioning Pools, and Snap Data Pools can be checked in this screen. Operation is easy – just choose the “operation object” and “what you want to do” from the server administrator’s view. Further extended operations for a specific individual ETERNUS DX system can be performed via separate tabs for:

- Overview of Configuration Settings
- Volume Management
- RAID Group Management
- Thin Provisioning Pool Management
- AdvancedCopy Management
- Connectivity Management
- Component Management
- System Management



The main features of the Web GUI are as follows:

- Display all relevant parameters, states, and settings of the storage system
- Wizard-supported initial settings provide instructions for the basic settings that are required to run the ETERNUS DX storage system – e.g., creation of RAID Groups, Volumes, and Pools
- Failure display which also indicates fault implications on host ports, LUN groups, volumes, or RAID groups, showing the complete picture with regards to the total extent and aftermath of failures.
- Setup of role-based user profiles, audit logging and alert routing e.g. call home.
- Maintenance including updating firmware, hot expansion, and repair.

For special configurations and management tasks all ETERNUS DX storage systems are also accessible via a Command Line Interface (CLI). This enables quick preparation of customized setup and maintenance operations or individual scripts for execution of repetitive operations.

ETERNUS SF Web Console

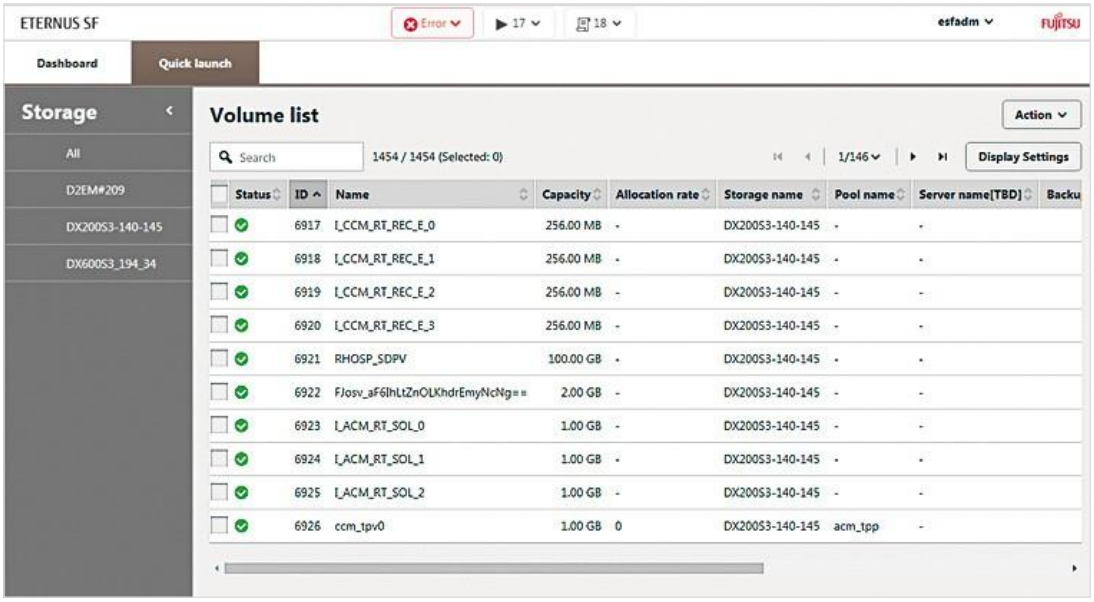
While the ETERNUS DX Web GUI's intended use is for initial setup and complex settings of the single array the ETERNUS SF storage management software is the umbrella solution for daily work.

The uniform management enables stable operation of multi-vendor storage networks, SAN, DAS, and NAS with integrated management of storage-related resources for the entire storage infrastructure:

- All generations of ETERNUS AF/DX disk storage systems from entry up to the high end
- Storage network components
- Hosts
- Virtualized server infrastructures

The Uniform Cross-Model User Interface

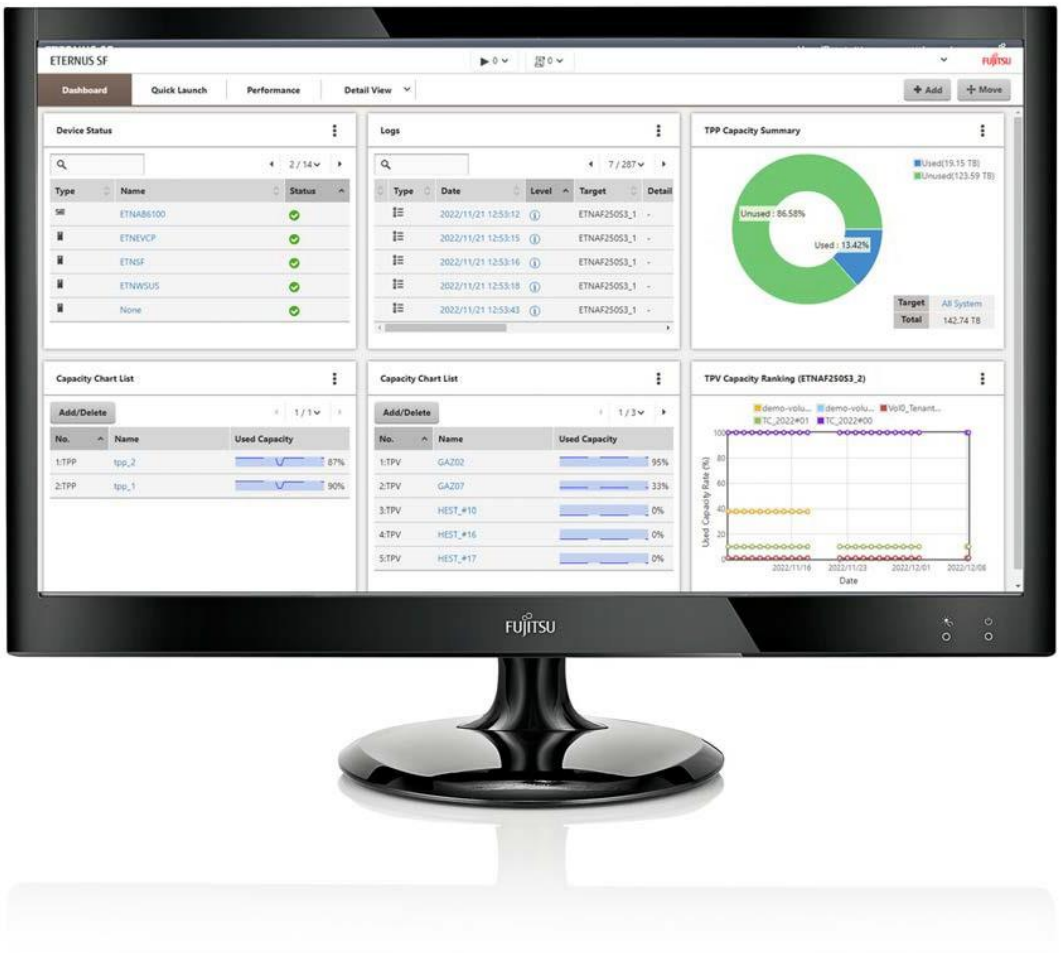
The user friendly graphical ETERNUS SF Web Console enables administrators to implement storage environments with ease and without high-level skills. An easy-to-understand resource tree structure displays all relevant status overviews and detailed information on components and events, with an intuitive focus on the objects and tasks relevant to users. The unified cross-model consistent GUI visualizes the status of multiple ETERNUS AF/DX storage systems with one single centralized console. Once mastered for a single system, the learning curve for administrators can be extended to the entire storage infrastructure within an enterprise. This results in improved availability, stable operation, and reduced operation management costs. In addition to the cost savings resulting from ergonomic and unified storage management, customers can avoid unnecessary vendor service costs because they can execute complex storage management operations themselves, without the expensive high-level skills associated with them.



Easy Configuration and Operation of Storage Systems and Data Center Infrastructures

A high degree of automation and the easy-to-learn, easy-to-handle graphical user interface make management tasks easier. Storage resource optimization (including implementation of policies for enhancing storage integration and operation, error discovery, health monitoring, capacity management, provisioning, cloning, backup, restore, and disaster recovery) are displayed with a consistent, user-friendly look and feel.

The user interface is based on a three-step operational concept: Select the type of action you want to perform from a well-structured menu, check the status and execute the task. Helpful wizards, system data visualization and automated routine administration tasks reduce the monitoring and management workload. The supplied web-based startup wizard is all what is needed for initial installation. Ongoing changes and system expansion are then supported by equally intuitive wizard-based operations. Administrators no longer need to spend hours poring over unfamiliar setup instructions and technical terminology. Anybody can perform the wizard-based configuration, and operations can be carried out without specialized storage expertise. Both block and file operations are seamlessly managed from the same interface.



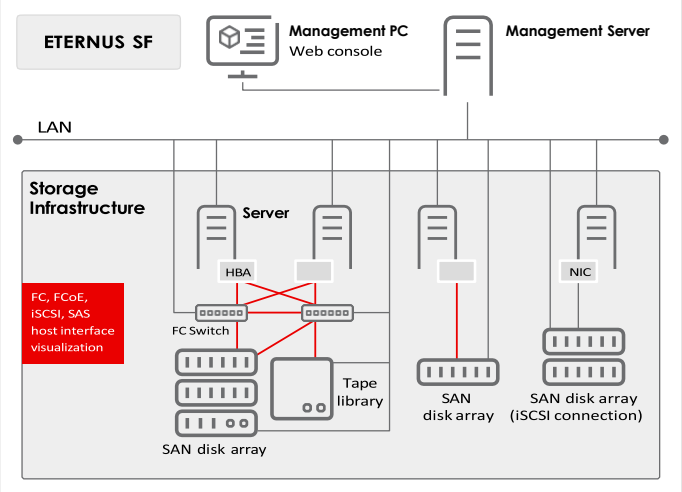
Grow with Your Needs

Within a single GUI window, ETERNUS SF storage management offers various specific functions that cover different administrative operations. If the ETERNUS DX storage infrastructure grows or customer demands become more complex, upgrading the management software is easy. This helps reduce the workload and protects the IT investment. A flexible and transparent license model guarantees that customers pay only for the functionalities they need, and thus can expand in step with rising requirements. The license key protection function for ETERNUS SF is structured according to functional and upgradable modules for each individual customer need.

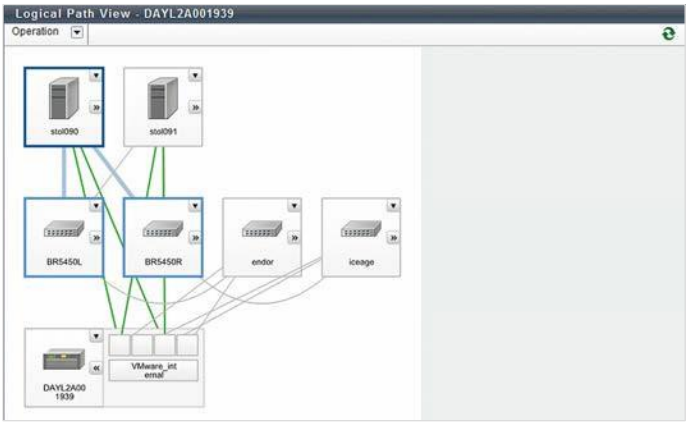
With an additional license, ETERNUS SF manages also limited AdvancedCopy functions of the storage system for internal disk-to-disk snapshots and clones. In business continuity scenarios, the management software also supports remote replication between ETERNUS DX systems even of different ETERNUS AF/DX generations. Each module and additional dedicated features can be activated by entering a license key in the ETERNUS SF integrated manager. When adding a license to an existing software installation, the current environment can be used without modification. This framework eliminates the need for separate and isolated tools to manage each class of storage device.

Configuration Management

ETERNUS SF supports stable system operation and provides all essential storage system lifecycle functions, such as improving end-to-end administrative efficiency for the setup, operation and monitoring of complex storage network infrastructures, including the installed servers, tape libraries, Fibre Channel switches and virtualized server environments.



The user-friendly web console simplifies the setup of ETERNUS DX storage systems and the management of the environments. ETERNUS SF displays the relationships and linkages between disk drives and other resources, such as application server file systems, connection paths, mirrored disks, and databases. This provides administrators with an accurate understanding of all resource relationships. It also allows them to proceed with storage expansions, resolve failures and recover operational status without problems more accurately. The ability to manage complex storage configurations and settings enables customers to implement storage environments with ease and without the need for high-level skills.

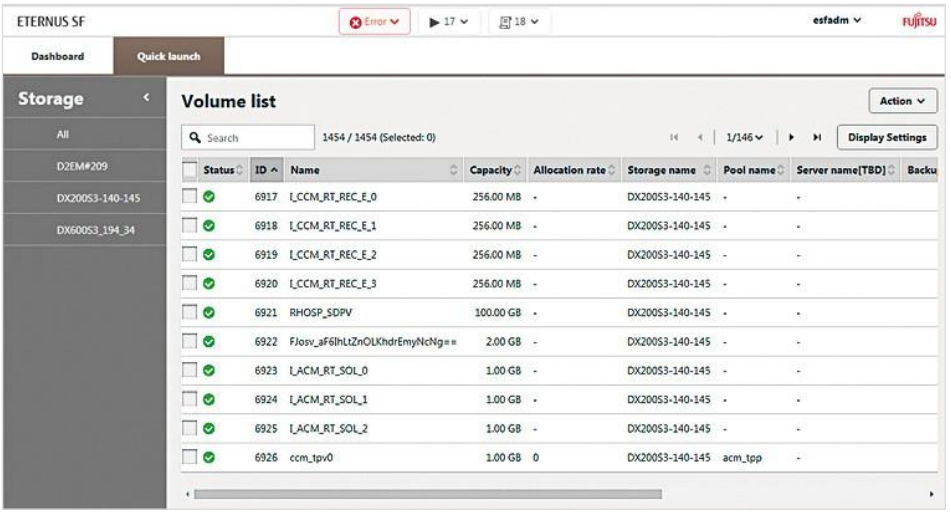


The main task of ETERNUS SF is the consolidated management of multiple storage arrays and their relationship with servers and network components in a data center.

Storage Management

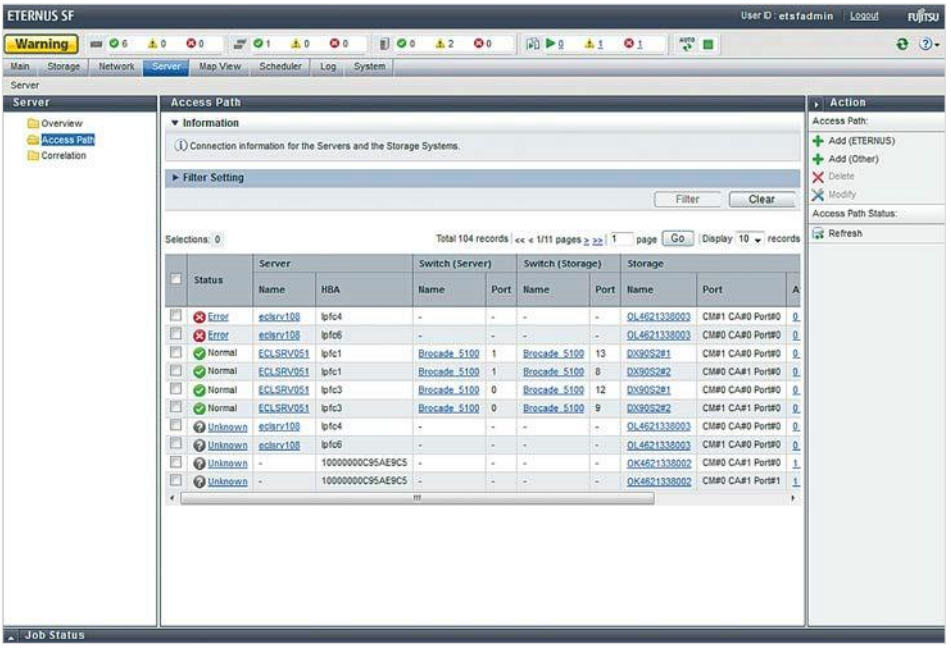
All major tasks which can be administrated by the array immanent Web GUI can also be executed via ETERNUS SF- setup for volumes, raid groups thin provisioning pools replication like snapshots etc.

In addition, it is mandatory to use ETERNUS SF for all tasks concerning automated storage tiering. It also offers a single-pane-of-glass view on all monitored ETERNUS DX arrays.



Connection Status Management

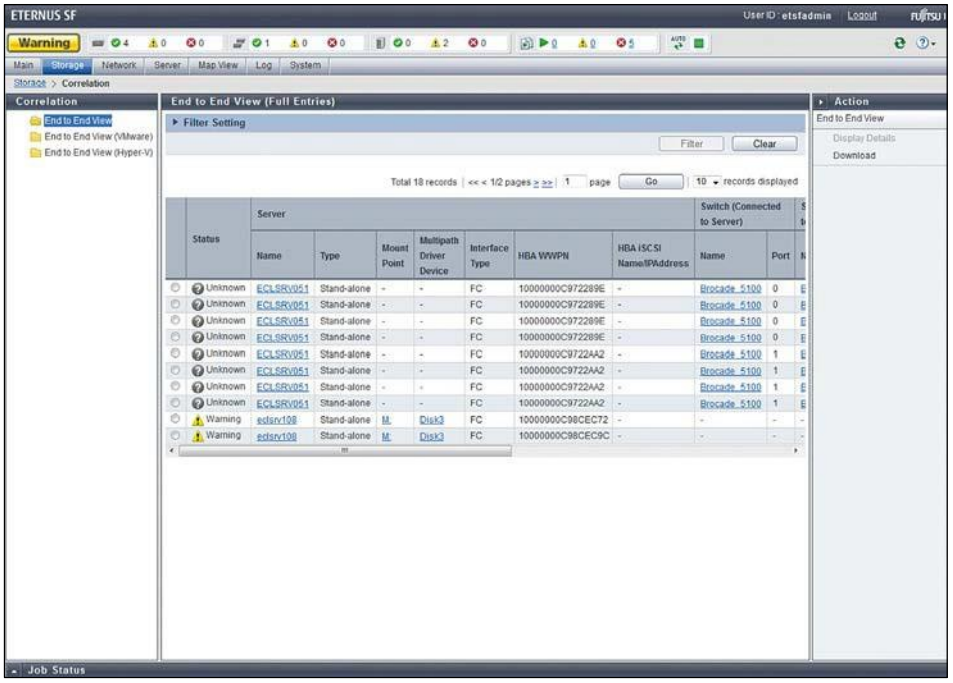
The web console displays the connection and device status in the Storage Area Network (SAN). This includes all physical connections for each storage device, and for each device connection to network components and servers, including VM guests.



Access Path Management

The access path management of ETERNUS SF supports easy setup, consistency verification and failure prevention. An access path (logical path) definition feature ensures easy and secure access path configurations.

Based on the connectivity/zoning information that has already been set in a device, an access path can be recognized automatically. In addition, devices can be registered manually if required. When devices are registered, their device information and the entire connection relationships between server nodes, Fibre Channel switches and disk storage systems are displayed. The intuitive overview helps prevent misuse and incorrect settings during SAN installation and operation.



ETERNUS SF – table-based view on end-to-end correlations

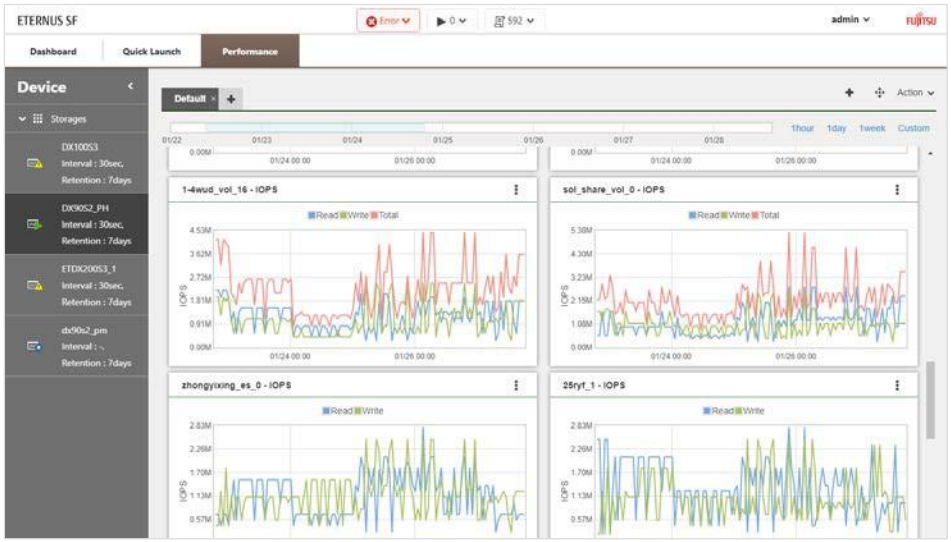
For managed access paths, the configuration definition of a device can be changed automatically as well as manually. Consistency checks verify the accuracy of the manual configuration changes. ETERNUS SF automatically notifies the administrator of any problems, such as incorrect security definitions, or access path anomalies caused by faults or unplugged cables. If the physical Fibre Channel cable or a complete SAN route is disconnected, the access path is displayed as an error. This enables pre-failure detection and service level improvements.

From both the storage and the server aspects ETERNUS SF offers a comprehensive, table-based view on end-to-end correlations of storage, network components, and servers including end-to-end-view for virtual machines in both VMware and Hyper-V environments.

Performance Monitoring

ETERNUS SF offers powerful, easy to use performance monitoring features for ETERNUS DX storage systems.

- The SAN component performance can be visualized at a glance, to detect and understand the performance bottlenecks and keep the system running optimally
- Multiple elements like volumes, CMs and ports can be displayed together to understand the performance flow
  - Up to 6 tabs of 24 different graphs per device can be displayed, with 5 elements on each graph
- The user can decide what needs to be displayed, and the layout to display it, in order to concentrate on the specific useful information
  - Each tab is fully customizable, and new graphs can be added with an easy-to-use wizard
  - A keyword filter makes the element selection fast and simple

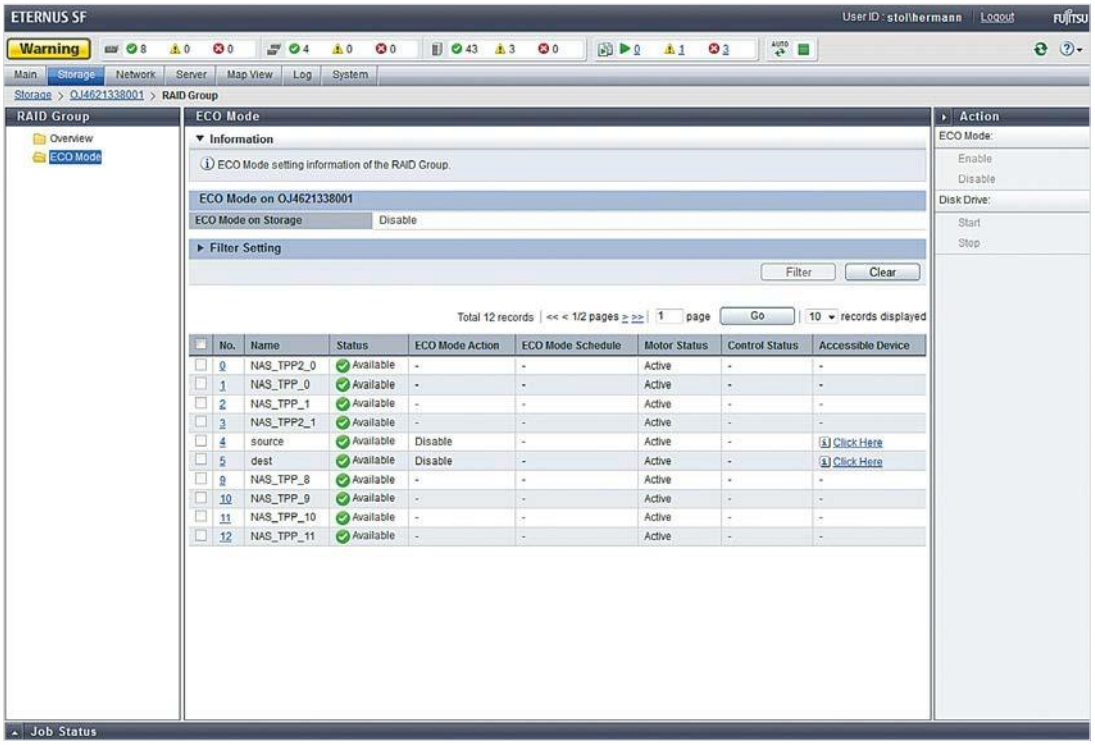


- Interactive navigation on the time scale allows surveying and discovery of significant data events from a broad range or a specific time interval
  - Changing scale from hour to day to week and back as well as interactive interval selection
  - Graphics can display real-time (30 sec interval) data, with automatic display update

Energy Savings – Eco-Mode/Eco-Mode Settings

Power consumption is one of the biggest contributors to the OPEX of any company. It is also a heavy burden on the environment. To achieve low power consumption for storage, ETERNUS DX systems are equipped with Eco-mode setting functions. Using MAID (Massive Array of Idle Disks) technology, ETERNUS DX disk drives have Eco-mode support to manage the on/off state of the disk drive. Eco-mode stops disk rotation at specified times based on customer's usage patterns. There are two variants: "System Eco-mode" and "RAID Group Eco-mode". Once System Eco mode is enabled Raid group Eco-mode can be set ON or OFF separately for each RAID group also on scheduled times, so it is possible to achieve high energy savings. The administrator can decide if only rotation is stopped, means the drive motor is switched off, or if the complete drive will be powered off resulting in even more energy savings.

When Eco-mode is activated, ETERNUS SF monitors the activity between servers and storage devices to get a full picture of server and disk storage system requirements. Energy consumption efficiency and system temperature can be displayed and checked or written to file. By turning off unused disks, energy consumption can be reduced. Data tracking also enables optimized use of electricity and air conditioning.



The following table shows a short comparison

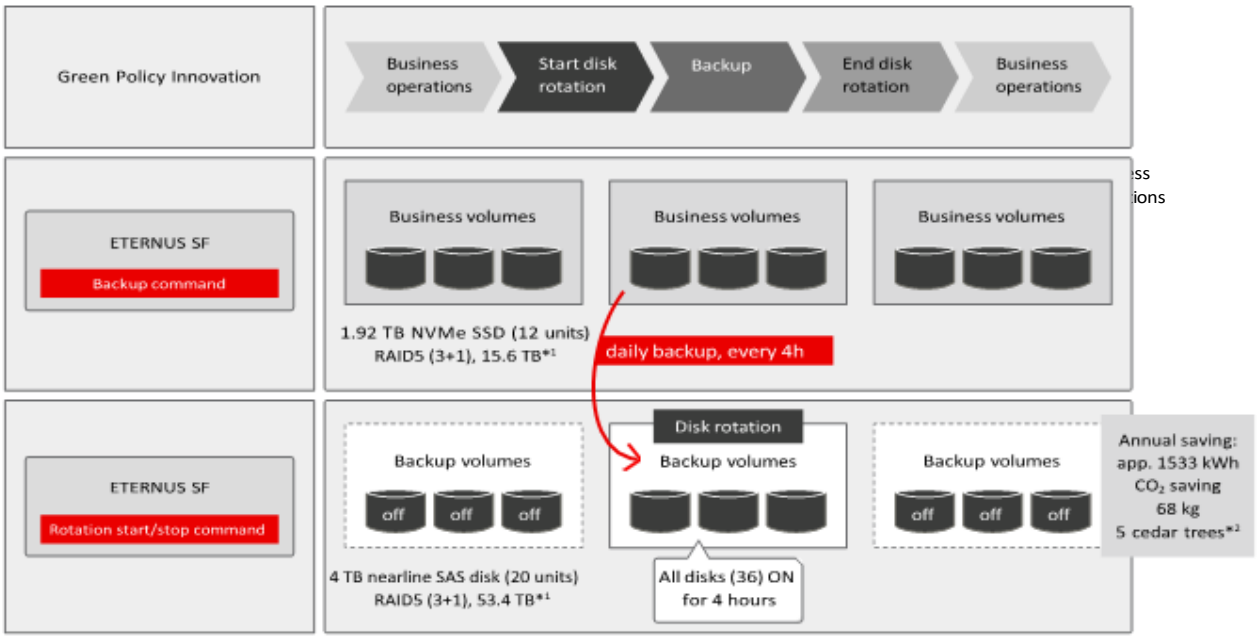
Power-consumption comparison			
Model	1. When disk is in use	2. When spindle of all disks stop (as percentage of 1.)	3. When power supply to all disk stops (as percentage of 1.)
DX600	100%	47.5%	22.1%

Conditions:

- Maximum configuration of HDD, cache and 16 Gbps FC interface
- 24 H time on Eco-mode state

Backup with Reduced Power Consumption

In conjunction with AdvancedCopy, the time-controlled Eco mode is used to reduce energy consumption by only powering the backup drives during the backup window. Such scheduled use of specific disks can be set up for individual RAID groups and backup operations. Power usage is reduced outside specified backup windows by stopping the rotation of the backup disks. Rotation stops if the disks are not accessed within specified time periods. In addition to time-controlled power sequencing, any data access command starts rotation providing access outside of the scheduled power on times. Full rotation is restored in about one minute.



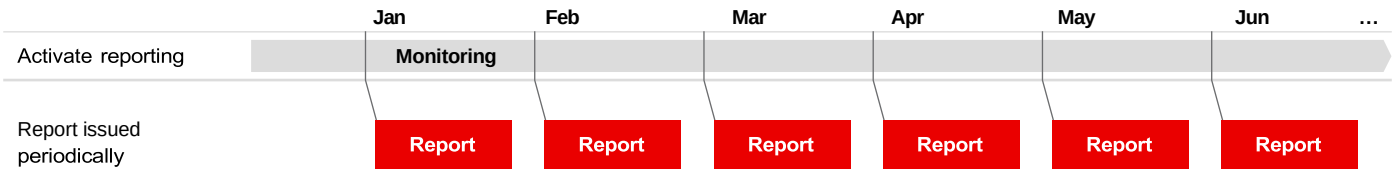
*1 logical capacity
*2 conversion from tree CO2 absorption

Reporting

Tracking the use of storage resources over time gets more and more important when storage environments get more complex and are used by many different users. ETERNUS SF provides a reporting function that issues regular reports of the volume allocation activity. Built in monthly standard reporting policies can be also customized using CLI commands.

Once activated for the array the reporting function collects capacity and usage time information for volumes connected to servers. This provides the required information to charge fees based on volume utilization and usage time.

Reports include information regarding physical servers, virtual server hosts and virtual machines, the individually allocated volume types with indication of physical and logical capacity, the usage period and service level indicators like disk type, RAID level or volume encryption.



The reports, issued in XML format, can be easily transformed, and integrated in documents or imported in an accounting application to charge the server operations individually on storage usage.

Information collectable by the reporting function	
Volume type and capacity	Physical capacity of standard volume
	Physical capacity of WSV
	Logical capacity of SDV
	Logical capacity of TPV
	Logical capacity of FTV
Usage period	Start date and time of use
	End date and time of use
Volume information	RAID level
	Disk type: NVMe-SSD, SED NVMe-SSD SSD, SED SSD, NL-SAS, SED NL-SAS, SAS, SED SAS
	Volume encryption

Virtualization with VMware

The introduction of server virtualization, such as VMware, has a significant impact on other infrastructure domains, namely network and storage. Server virtualization is no longer just a topic for server operators; it also affects the management of storage and networking equipment. The relationship to storage is simple as the physical representation of virtual servers (virtual machines – VMs) is just files – files that are in most cases stored on external storage arrays. Server operations have to deal mostly with storage. This can create administrative complexity as additional knowledge has to be acquired; it also requires more procedural alignment between the various experts and a lot of information has to be exchanged. This chapter provides a short overview where Fujitsu's ETERNUS DX storage systems can be integrated in VMware environments.

- A plug-in enables VMware administrators to view the ETERNUS DX storage system directly from the vSphere GUI.
- The next level of integration is to enable the direct exchange of information between ETERNUS DX storage systems and vSphere, for example, the current system status, system events, or alerts. This helps VMware administrators during virtual machine provisioning to optimize the placement of virtual machines should environmental conditions change and also to automate corrective actions to prevent availability or performance problems relating to the storage system. For this purpose, ETERNUS DX supports VMware's VASA interface (VMware vSphere Storage APIs for Storage Awareness).
- Storage-related VMware actions, e.g., copying a virtual machine, can be offloaded to the ETERNUS DX storage system, thus saving performance and network bandwidth. For this purpose, ETERNUS AF/DX supports VMware's VAAI interface (vStorage APIs for Array Integration).
- By nature, server virtualization facilitates the realization of disaster recovery concepts as it simply requires the files representing a VM to be available on a failover site. Complete DR can be implemented efficiently by integrating ETERNUS DX and its replication functions with VMware SRM (Site Recovery Manager).
- ETERNUS DX with VMware vSphere Virtual Volumes (VVOL) simplifies storage operations through policy-driven automation that enables more agile storage consumption for VMs and dynamic adjustments in real-time. It eliminates operational dependencies and complexity between the vSphere administrator and the storage administrator. As this enhancement is relatively new, let's dive slightly deeper into the details:

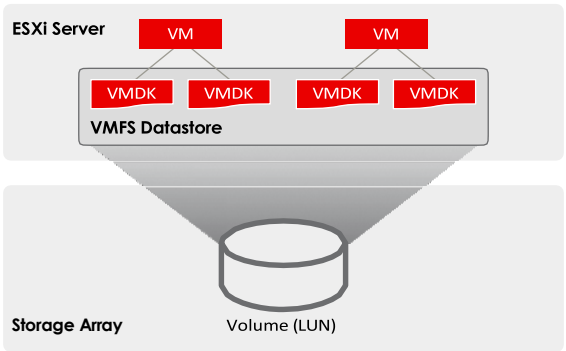
VVOL Integration

VMware vSphere Virtual Volumes, commonly referred to as VVOL, are a development of Software Defined Storage (SDS) that VMware has built to make it easier for administrators to deploy and manage virtual machines in systems using the ESXi hypervisor and associated routine software stacks.

ETERNUS SF supports VVOL via VASA and offers capabilities as Virtual Machine Backup, Automated Storage tiering, Automated QoS, Extreme Cache Involvement and Encryption for easy deployment granularly to VMs rather than to volumes. Thus, the deployment of VMs onto storage systems becomes far more straightforward and rapid, service levels supplied by VMs will be able to meet changing business demands without exhausting the IT teams running them or requiring ever greater levels of storage skills.

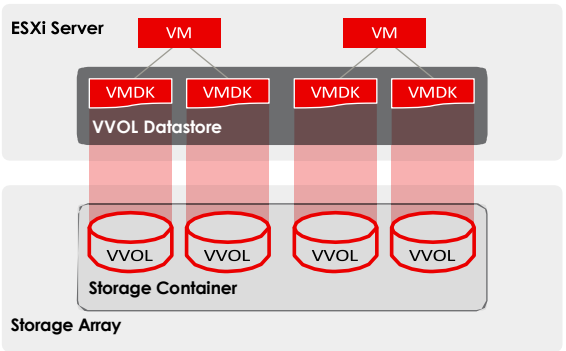
Without VVOL

- A volume defined by a VM becomes a VMDK file
- VMDK files are stored into a VMFS datastore which is a file system on storage volume



With VVOL

- A volume defined by a VM becomes a VVOL
- Virtual volumes are defined directly by the storage array under the logical storage container pool



For more details refer to the following whitepaper: Integration of ETERNUS DX Storage Systems in VMware Environments

Summary and Conclusion

The ETERNUS DX product series is the perfect choice for customers looking for a flexible storage solution that adapts according to their business changes. Built on powerful performance hardware architecture it ensures efficient storage consolidation while providing flexibility to respond to changing business requirements.

The uniform management software, ETERNUS SF, reduces the total cost of ownership, simplifies monitoring and management, and helps achieve business continuity.

Furthermore, innovative advanced software functions, particularly in the area automated Quality of Service management, allow maintaining stringent Service Level Agreements, thus making the ETERNUS DX storage systems – the next generation data storage solutions for the digital world.

ETERNUS Online Storage

	ETERNUS DX600	ETERNUS DX900	ETERNUS DX8900
Architecture	Flexible and seamless design with uniform storage management		
Segment	Scalable midrange systems		Enterprise systems
Maximum raw capacity SSD	28,754 TB	69,304 TB	132,710 TB
Maximum raw capacity HDD	8,424 TB	20,304 TB	38,880 TB
Maximum disk drives	960	2,304	4,608
Storage controllers	2	2–4	2–24
Maximum cache capacity	2 TB	4 TB	24 TB
Maximum second-level cache (Extreme Cache Pool)	25.6 TB	51.2 TB	307.2 TB
Host interfaces	8/16/32/64 Gbps FC, 1/10 Gbps iSCSI		
Storage management	ETERNUS SF V16 software suite		
Continuity management	Remote Equivalent Copy (REC)		
	Storage Cluster – transparent failover		
	Local Advanced Copy		
Performance management	Automated Storage Tiering		
	Automated Quality of Service		
Information security management	Self-encrypting drive		
	Controller-based encryption		
Availability management	Reliability/RAID protection		
	Redundant controller and components		
Capacity management	Thin Provisioning		
	Deduplication and Compression	Compression	
Virtualization	VMware Virtual Volumes (VVOL) Support		

1 Maximum raw capacity depends on available SSD types | 2 Calculation based on deduplication/compression factor of five

Appendix

Operational Functions Overview

ETERNUS DX Hardware	Web GUI /CLI
Operational Area	**Function Overview**
Single Storage System Management	Storage Configuration
	Thin Provisioning
	Temperature and Power Consumption
	QoS by application prioritization control
	Eco mode configuration
Single Storage Device Management	Health and Status Overview, Eco Status*
Basic internal AdvancedCopy Function	SnapOPC+

ETERNUS SF V16 Software	Web Console
Operational Area	**Feature**
Storage System Management	Storage Configuration
	Thin Provisioning visualization
	Storage hierarchy control/Automated Storage Tiering* (requires Thin Provisioning)
	SAN Management (switch setting, access path mgmt., correlation mgmt.)
	Automated QoS Management
	Performance monitoring, analysis, history view, and alerts for ETERNUS AF/DX, FC switches
	Temperature and Power Consumption visualization
	Eco mode configuration
Storage Device Management	Health and Status Overview (ETERNUS AF/DX storage, 3rd vendor storage, FC/FCoE switches, Server multipath, Eco status, VM guest view)
	Capacity monitoring (Assigned/Free space)
AdvancedCopy Function	SnapOPC+, OPC/QuickOPC, EC, REC
Backup Management	Generation Management, backup destination pool, NAS Backup
Business Continuity Management	Storage Cluster
Application Integration	Microsoft Volume Shadow Copy Service (VSS) support
	Exchange Server
	SQL Server
	Oracle
	Fujitsu Software Symfoware
	VMware consistent backup
	VMware SRM
	VMware VASA
	VMware VAAI

Related Documents

- ETERNUS DX Storage Cluster