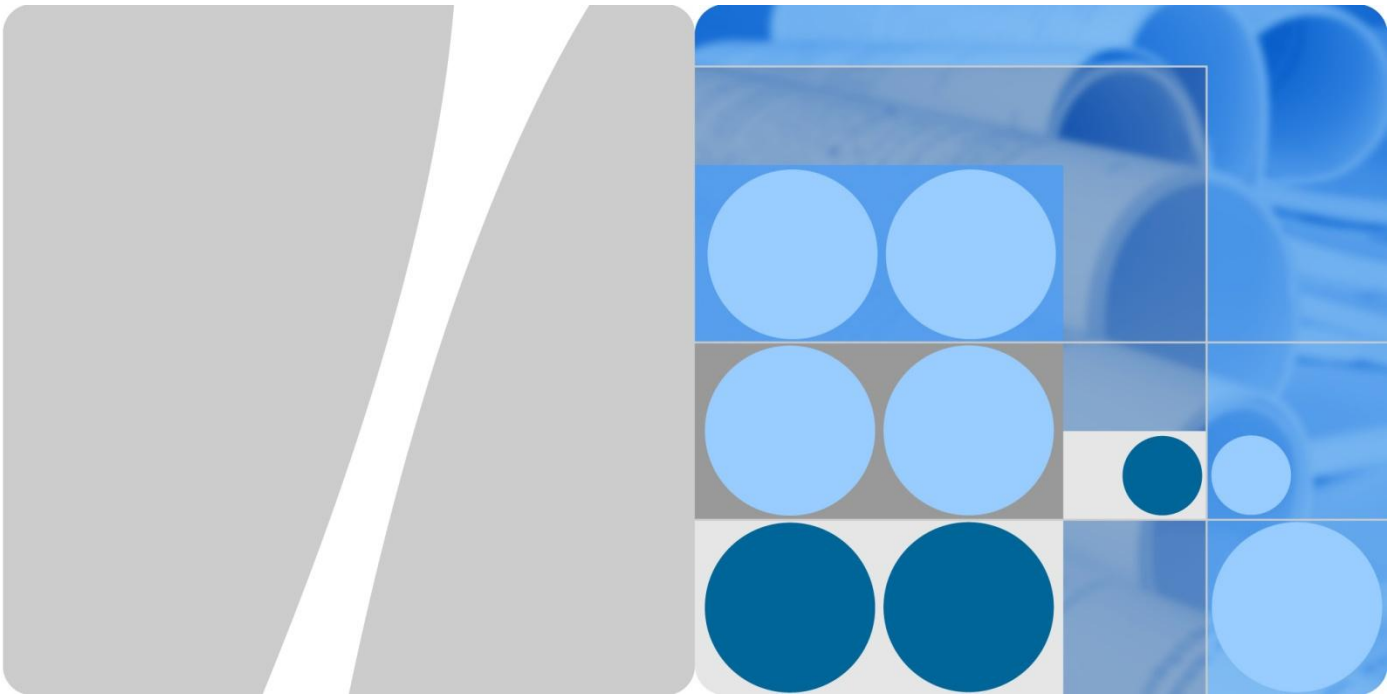

HUAWEI OceanStor V3 DAS

Technical White Paper

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OceanStor V3 DAS Technical White Paper

Key words: DAS, JBOD

Abstract: Introduces the working principle of DAS and its applications.

List of Abbreviations:

Abbreviations	Full spelling
DAS	Direct-Attached Storage
JBOD	Just a Bunch Of Disks

1 Background

Direct-attached storage (DAS), also called JBOD, is a mode for connecting storage devices and servers, indicating that storage devices use cables such as optical fibers to directly connect to servers.

As one of the earliest storage modes, DAS is the basic storage and is widely used in PCs and servers for low-end markets.

DAS is replaced by NAS, SAN, and distributed storage because it is suitable for direct connection of no more than four servers. It expands the capacity of built-in disks and directly connects to servers through a host adapter such as a SCSI card, SAS HBA, and FC HBA. However, DAS is not as flexible and reliable as other storage modes and does not support advanced functions such as snapshot, clone, or disaster recovery.

DAS is widely used to meet storage requirements in the following scenarios: DAS storage resources are used to build storage pools as software-defined storage is gaining popularity in the era of big data, cloud computing, and Internet. Rapid data growth needs increasing space to store cold data. Lower costs and on-demand expansion are required by X86 hardware adopted by HPC and Internet.

2 Concepts and Principles

2.1 Basic Concepts

1. DAS architecture

   DAS only provisions storage capacities to servers and the servers connected with the DAS provide storage services and protocols. DAS consists of system enclosures, disk and expansion modules, fans, power supplies, and disks.

   Some DAS products support outband management and enable customers to manage DAS as servers while some DAS products allow in-band management of DAS customers by servers. The networking supports both One Server + DAS cascading and Multi Server failover + DAS.

2. DAS application

   Although data storage services and other functions are provided by servers, DAS must be compatible with different HBAs and operating systems.

   As software-defined storage is gaining popularity, large-capacity applications on Internet Service Provider (ISP), virtualization and cloud platforms of large enterprises, and high performance computing (HPC) require standard computing and storage resources independent from each other, communication and management through standard protocols, as well as independent capacity expansion. Some large data storage scenarios also require to save storage space by increasing storage density. DAS is widely used in these scenarios.

3. Introduction to DAS

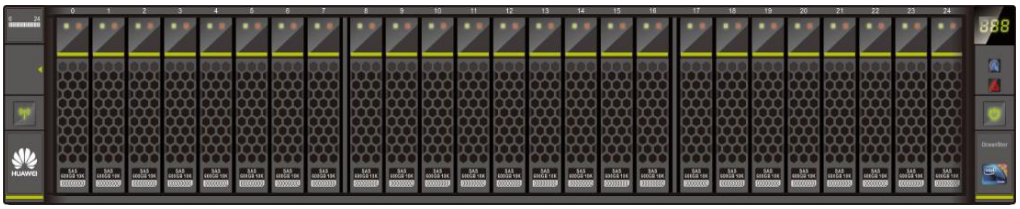
   DAS uses disk enclosures of 2 U 25, 4 U 24, and 4 U 75 slots. All its back-end ports and disk ports support a rate of 12 Gbit/s and mainstream commands for SES and SMP protocols. DAS has two networking modes: one server + DAS cascading networking and multi server failover+ DAS cascading networking. DAS provides the following customer benefits:

   (1) Standard SES 3.0 and SMP commands for connection to standard computing resources.

   (2) Multiple networking methods for different customer application scenarios.

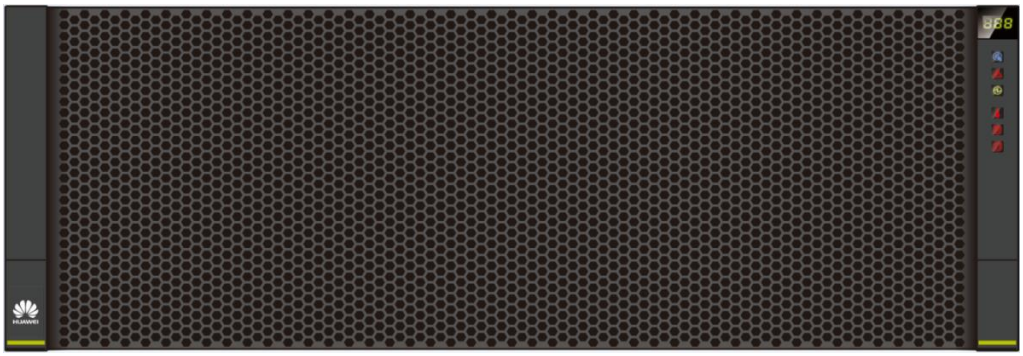
   (3) 4 U 75-slot high-density disk enclosures to meet the requirements of DAS when the site space is limited, as well as 2 U 25-slot and 4 U 24-slot common disk enclosures to meet the requirements of DAS in standard cabinets.

2 U 25-slot disk enclosure



4 U 24-slot disk enclosure

4 U 75-slot disk enclosure



2.2 V3 DAS32525U2 Structure

A disk enclosure adopts a modular design and consists of a system enclosure, two expansion modules, two power supplies, and a disk module.

1. System enclosure: 25 disks, 2 U high, 488 mm deep. A system enclosure integrates a backplane to provide signal and power connectivity among modules.
2. Expansion module: An expansion module has two 12 Gbit/s expansion ports P0/P1 and one board has a 12 Gbit/s 36-port expander. An expansion module is connected to engines and disk enclosures through expansion ports to support communication and data transmission between engines and disk enclosures.
3. Power supply: The storage system supports dual power supplies. One power supply can ensure that the disk enclosure works correctly in maximum power consumption mode.
4. Disk module: A disk module provides storage capacity for service data and functions as system coffers.

2.3 V3 DAS32435U4 Structure

A disk enclosure adopts a modular design and consists of a system enclosure, two expansion modules, two power supplies, two fans, and a disk module.

1. System enclosure:A system enclosure integrates a backplane to provide signal and power connectivity among modules.
2. Expansion module: An expansion module has two 12 Gbit/s expansion ports P0/P1 and one board has a 12 Gbit/s 36-port expander. An expansion module is connected to engines and disk enclosures through expansion ports to support communication and data transmission between engines and disk enclosures.
3. Power supply:The storage system supports dual power supplies. One power supply can ensure that the disk enclosure works correctly in maximum power consumption mode.
4. Fan module: A fan module provides heat dissipation and supports the normal running of the disk enclosure in maximum power consumption mode.
5. Disk module:A disk module provides storage capacity for service data and functions as system coffers.

2.4 V3 DAS37535U4 Structure

A disk enclosure adopts a modular design and consists of a system enclosure, two expansion modules, four power supplies, two fans, and a disk module.

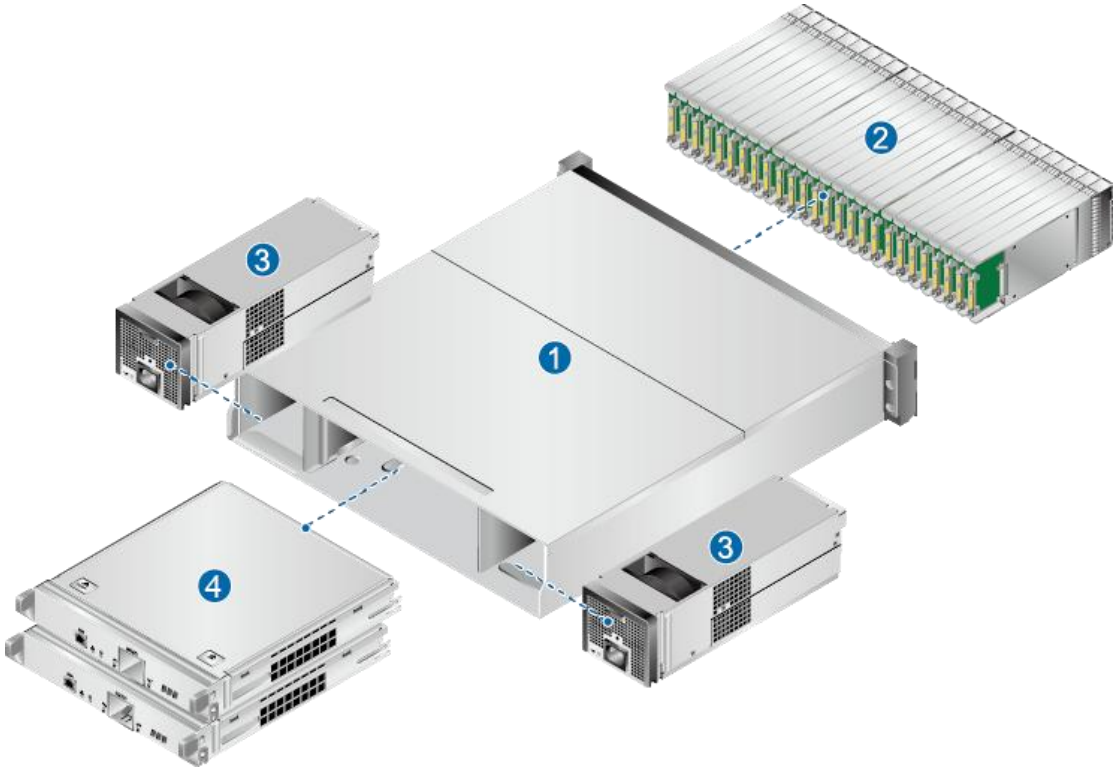
1. System enclosure:A system enclosure integrates a backplane to provide signal and power connectivity among modules.Specifications: 75 disks, 4 U high, 790 mm deep.
2. Expansion board: Each expansion module provides two 12 Gbit/s upstream expansion ports and two 12 Gbit/s downstream expansion ports. An expansion module is connected to engines and disk enclosures through expansion ports to support communication and data transmission between engines and disk enclosures.
3. Power supply: 1200 W; 2+2 redundancy (4 power supplies)Two power supplies enable the disk enclosure to work correctly in maximum power consumption mode.
4. Disk maintenance method: cable managers.
5. Fan module: Two fan field replaceable units (FRUs), each containing 6 fans. Speed of the fan modules can be adjusted based on ambient and disk temperatures.

3 Services and Functions

3.1 V3 DAS32525U2 Disk Enclosure

The disk enclosure is a 2 U DAS device based on a redundant architecture through backplane interconnection, and supports a maximum of 25 2.5-inch SSDs. The enclosure manages disks, and interconnects and provisions service access. It consists of a system enclosure, two expansion modules, two power supplies, and SSDs.

Figure 3-1 Hardware architecture of a disk enclosure



1	System enclosure	2	Disk module
3	Power module	4	Expansion module

System specifications

Parameter	Value
Onboard port	12 Gbit/s Mini SAS HD
SAS cable	1 m, 3 m, 5 m
Dimensions	488 mm x 447 mm x 86.1 mm
Weight	17.5 kg (without disks)
Entire system power consumption (with disks)	Max power consumption: 354 W Typical power consumption: 320 W Idle power consumption: 300 W
Entire system noise	67.5 dB
	52
System model	2 U

Parameter	Value
Redundant power supplies	1+1
Power supply	100 V to 240 V AC ±10%, 10 A, single phase, 50/60 HZ
Fan module	Integration of power supplies and fans
	Fans (3+1): The system has two replaceable power supplies and each power supply has two fans. The system allows failure of one fan out of four fans.
Max. number of disks	25
Backplane performance	12 Gbit/s

3.1.1 Expansion Module

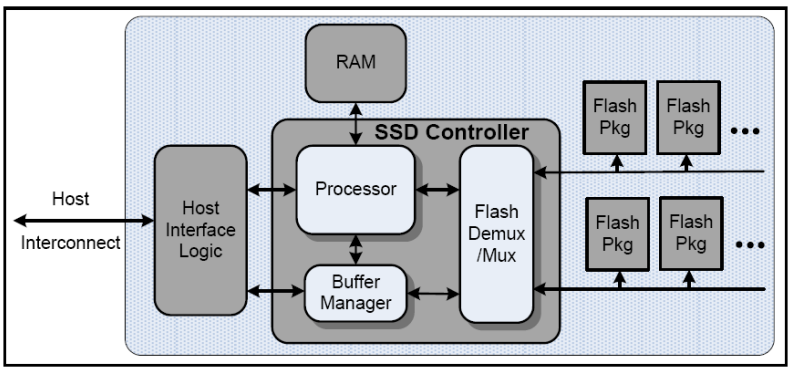
The management plane of an expansion board manages power supplies, fans, and SSDs in the system. The service plane provides one 12 Gbit/s Mini SAS HD upstream link and one 12 Gbit/s Mini SAS HD downstream link through an SAS expander and writes data to and reads data from disks.

3.1.2 Self-developed SSD Architecture

An SSD consists of a control unit and a storage unit (mainly flash memory chips). The control unit contains an SSD controller, host interface, and random access memory (RAM) module. The storage unit contains NAND flash chips.

1. Host interface: the protocol and physical interface used by a host to access an SSD. NVMe, SAS, NoF (NVMe over Fabric) are supported.
2. SSD controller: a core SSD component responsible for read and write access from a host to the back-end media and for protocol conversion, table entry management, data caching, and data checking.
3. RAM: a component responsible for the Flash Translation Layer (FTL) table and data caching to provide fast data access.
4. NAND FLASH: a physical component that stores data.

Figure 3-2 SSD hardware architecture



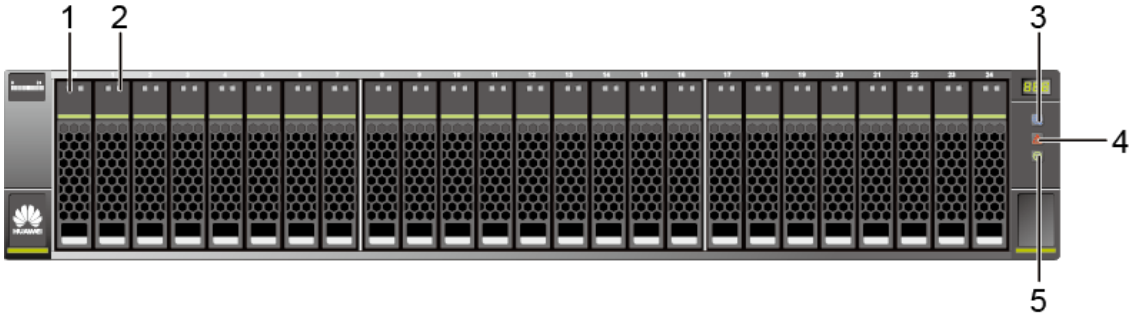
3.1.3 Indicator Introduction

After a disk enclosure is powered on, you can check the current operating status of the disk enclosure by viewing its indicators.

1. Indicators on the front panel

   The following figure shows the indicators on the front panel of a disk enclosure.

Figure 3-3 Indicators on the front panel of a disk enclosure



1	Running indicator of a disk module	2	Alarm/Location indicator of a disk module
3	Location indicator of a disk enclosure	4	Alarm indicator of a disk enclosure
5	Power indicator of a disk enclosure		

The following table describes the indicators on the front panel of a disk enclosure.

Table 3-1 Description of the indicators on the front panel of a disk enclosure

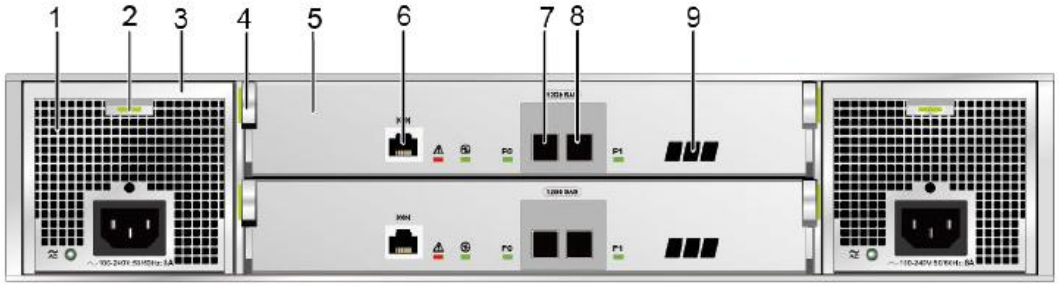
Module	No.	Indicator Type	Description
Disk module	1	Running indicator of a disk module	• Steady green: The disk module is working correctly. • Blinking green: Data is being written to and read from the disk module. • Off: The disk module is not powered on or is powered on incorrectly.
	2	Alarm/Location indicator of a disk module	• Steady red: The disk module is faulty. • Blinking red: The disk module is being located. • Off: The disk module is working correctly or is hot-swappable.
System enclosure	3	Location indicator of a disk enclosure	• Blinking blue: The disk enclosure is being located. • Off: The disk enclosure is not detected.
	4	Alarm indicator of a disk enclosure	• Steady red: An alarm is generated in the disk enclosure.

Module	No.	Indicator Type	Description
			• Off: The disk enclosure is working correctly.
	5	Power indicator of a disk enclosure	• Steady green: The disk enclosure is powered on. • Off: The disk module is not powered on.

2. Indicators on the rear panel

The following figure shows the indicators on the rear panel of a disk enclosure.

Figure 3-4 Indicators on the rear panel of a disk enclosure



1	Power supply	2	Power supply latch
3	Power supply handle	4	Expansion module handle
5	Expansion module	6	Serial port
7	Mini SAS HD P0 expansion port	8	Mini SAS HD P1 expansion port
9	ID display of a disk enclosure		

The following table describes the indicators on the rear panel of a disk enclosure.

Table 3-2 Description of the indicators on the rear panel of a disk enclosure

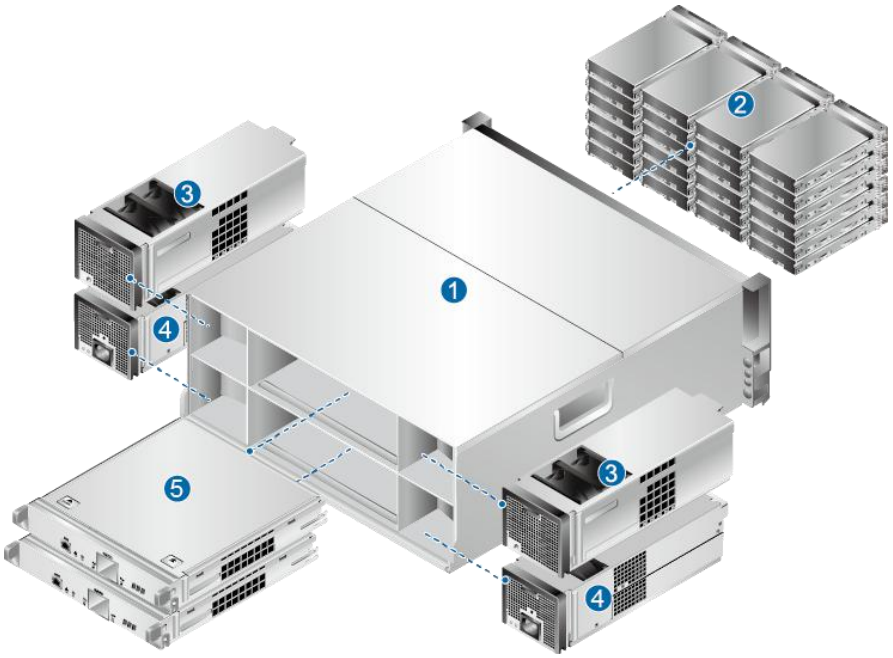
Module	No.	Indicator	Description
Expansion module	1	Expansion module alarm indicator	• Steady red: An expansion module alarm is generated. • Off: The expansion module is working correctly.
	2	Expansion module power indicator	• Steady green: The expansion module is powered on properly. • Off: The expansion module is not powered on.
	3	Mini SAS HD expansion port indicator	• Steady blue: The link to the expansion port is up, and the data transfer rate is 4 x 12 Gbit/s. • Steady green: The link to the expansion port is normal, and the data transmission rate is 4 x 6 Gbit/s or 4 x 3 Gbit/s. • Steady red: The port is faulty.

Module	No.	Indicator	Description
			• Off: The link to the expansion port is down.
Power supply	4	Power supply running/alarm indicator	• Steady green: The power supply is correct. • Blinking green: The power input is normal but the disk enclosure is powered off. • Steady red: The power supply is faulty. • Off: No external power is input.

3.2 V3 DAS32435U4 Disk Enclosure

The disk enclosure is a 4 U 24-slot DAS device based on a redundant architecture through backplane interconnection, and supports a maximum of 24 3.5-inch SSDs. The enclosure manages disks, and interconnects and provisions service access. It consists of a system enclosure, two expansion modules, two power supplies, and disks.

Figure 3-5 Hardware architecture of a disk enclosure



1	System enclosure	2	Disk module
3	Fan module	4	Power supply
5	Expansion module		

System specifications

Parameter	Value
Onboard port	12 Gbit/s Mini SAS HD

Parameter	Value
SAS cable	1 m, 3 m, 5 m
Dimensions	488 mm x 447 mm x 175 mm
Weight	26.5 kg (without disks)
Entire system power consumption (with disks)	Max power consumption: 500 W Typical power consumption: 343 W Idle power consumption: 316 W
Entire system noise	67.5 dB
System model	4 U
Redundant power supplies	1+1
Power supply	100 V to 240 V AC ±10%, 10 A, single phase, 50/60 HZ
Fan module	Integration of power supplies and fans
	Fans (5+1): The system has two replaceable power supplies and each power supply has three fans. The system allows failure of one fan out of five fans.
Max. number of disks	24
Disk type	NL-SAS
Backplane performance	12 Gbit/s

3.2.1 Expansion Module

The management plane of an expansion board manages power supplies, fans, and disks in the system. The service plane provides one 12 Gbit/s Mini SAS HD upstream link and one 12 Gbit/s Mini SAS HD downstream link through an SAS expander and writes data to and reads data from disks.

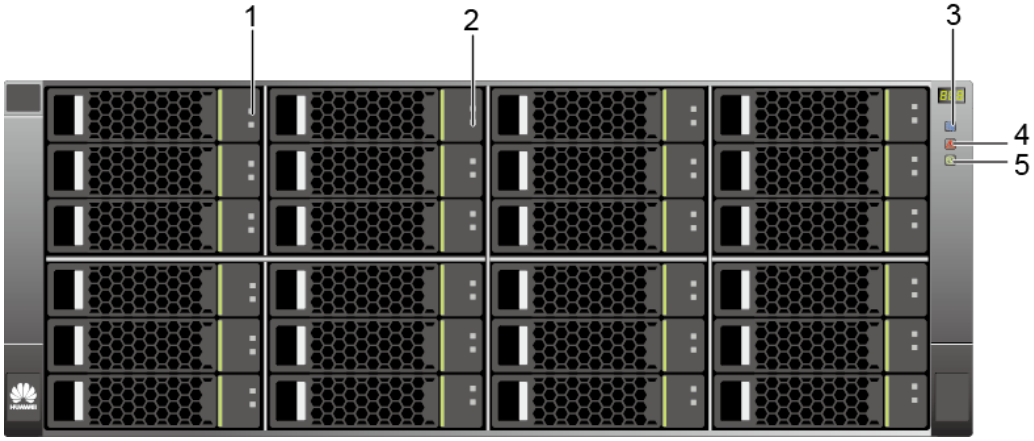
3.2.2 Indicator Introduction

After a disk enclosure is powered on, you can check the current operating status of the disk enclosure by viewing its indicators.

1. Indicators on the front panel

   The following figure shows the indicators on the front panel of a disk enclosure.

Figure 3-6 Indicators on the front panel of a disk enclosure



1	Running indicator of a disk module	2	Alarm/Location indicator of a disk module
3	Location indicator of a disk enclosure	4	Alarm indicator of a disk enclosure
5	Power indicator of a disk enclosure		

The following table describes the indicators on the front panel of a disk enclosure.

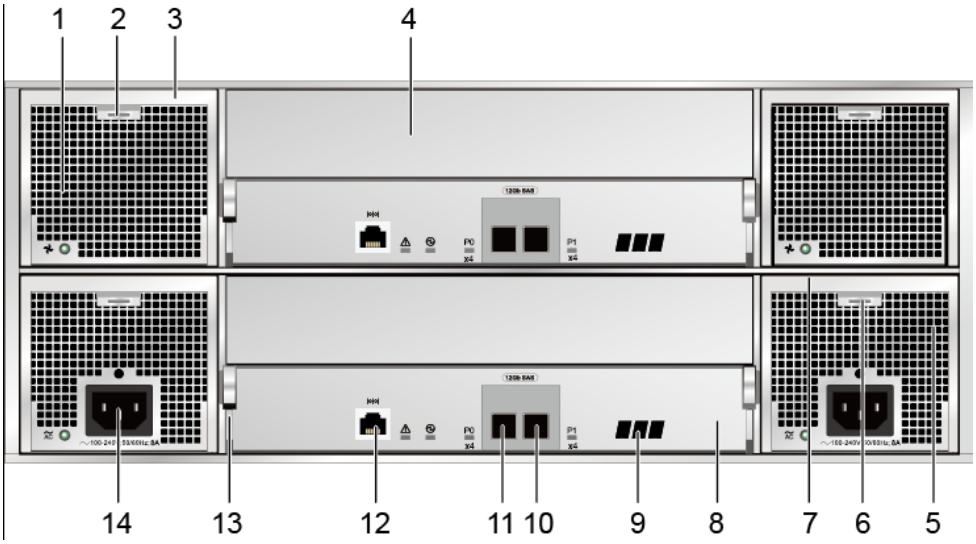
Table 3-3 Description of the indicators on the front panel of a disk enclosure

Module	No.	Indicator Type	Description
Disk module	1	Running indicator of a disk module	• Steady green: The disk module is working correctly. • Blinking green: Data is being written to and read from the disk module. • Off: The disk module is not powered on or is powered on incorrectly.
	2	Alarm/Location indicator of a disk module	• Steady red: The disk module is faulty. • Blinking red: The disk module is being located. • Off: The disk module is working correctly or is hot-swappable.
System enclosure	3	Location indicator of a disk enclosure	• Blinking blue: The disk enclosure is being located. • Off: The disk enclosure is not detected.
	4	Alarm indicator of a disk enclosure	• Steady red: An alarm is generated in the disk enclosure. • Off: The disk enclosure is working correctly.
	5	Power indicator of a disk enclosure	• Steady green: The disk enclosure is powered on. • Off: The disk enclosure is not powered on.

2. Indicators on the rear panel

The following figure shows the indicators on the rear panel of a disk enclosure.

Figure 3-7 Indicators on the rear panel of a disk enclosure



1	Fan module	2	Fan module latch
3	Fan module handle	4	Filler panel
5	Power supply	6	Power supply latch
7	Power supply handle	8	Expansion module
9	ID display of a disk enclosure	10	Mini SAS HD P0 expansion port
11	Mini SAS HD P1 expansion port	12	Serial port
13	Expansion module handle	14	Power socket

The following table describes the indicators on the rear panel of a disk enclosure.

Table 3-4 Description of the indicators on the rear panel of a disk enclosure

Module	No.	Indicator	Description
Fan module	1	Fan module running/alarm indicator	• Steady green: The fan module is working correctly. • Steady red: The fan module is faulty. • Off: The fan module is powered off.
Power supply	2	Power supply running/alarm indicator	• Steady green: The power supply is correct. • Blinking green: The power input is normal but the disk enclosure is powered off. • Steady red: The power supply is faulty. • Off: No external power is input.
Expansion module	3	Mini SAS HD expansion port	• Steady blue: The link to the expansion port is up, and the data transfer rate is 4 x 12 Gbit/s.

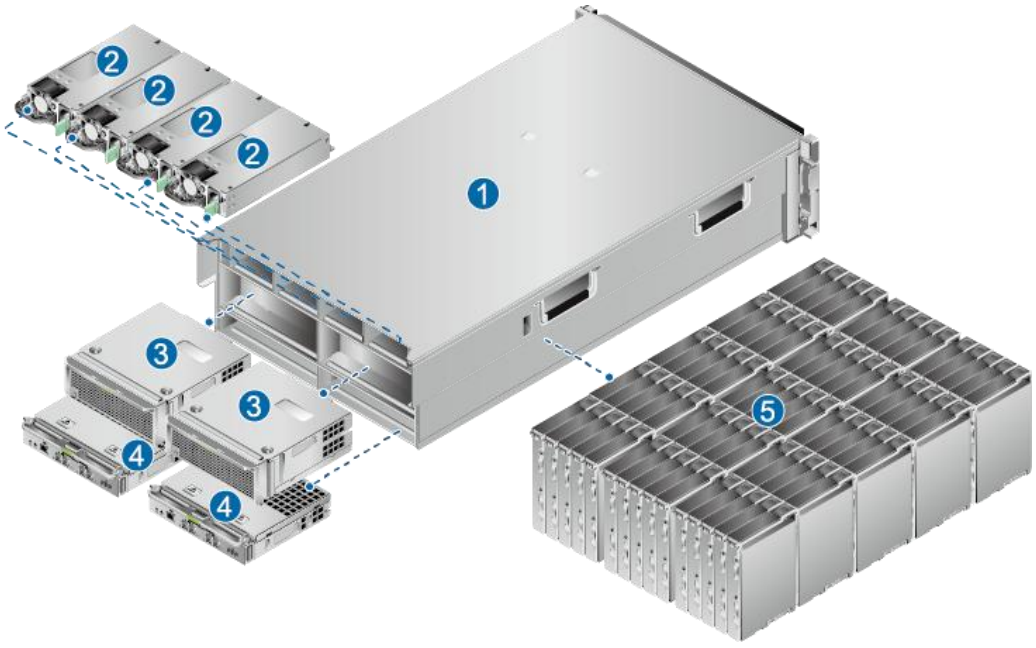
Module	No.	Indicator	Description
		indicator	• Steady green: The link to the expansion port is normal, and the data transmission rate is 4 x 6 Gbit/s or 4 x 3 Gbit/s. • Steady red: The port is faulty. • Off: The link to the expansion port is down.
	4	Expansion module power indicator	• Steady green: The expansion module is powered on properly. • Off: The expansion module is powered off.
	5	Expansion module alarm indicator	• Steady red: An expansion module alarm is generated. • Off: The expansion module is working correctly.

3.3 V3 DAS37535U4 Disk Enclosure

The disk enclosure is a 4 U 75-slot DAS device based on a dual-controller architecture through backplane interconnection, and supports a maximum of 75 3.5-inch SSDs. The enclosure manages disks, and interconnects and provisions service access. It consists of a system enclosure, two expansion modules, four 1200 W power supplies, and disks.

The following figure shows the overall architecture of the high-density disk enclosure.

Figure 3-8 Hardware architecture of a disk enclosure



1	System enclosure	2	Power supply
3	Fan module	4	Expansion module

5 Disk module

System specifications

Parameter	Value
Onboard port	12 Gbit/s Mini SAS HD
SAS cable	3 m, 5 m
Dimensions	790 mm x 446 mm x 176.5 mm
Weight	50.5 kg
Entire system power consumption (with disks)	Max power consumption: 1008 W Typical power consumption: 857 W Idle power consumption: 844 W
Entire system noise	67.5 dB
System model	4 U
Redundant power supplies	2 + 2
Power supply	100 V to 240 V AC ±10%, 10 A, single phase, 50/60 HZ DC: -48 V to -60 V, ±20%, 26 A
Fan module	Independent fans
	Fans (11+1): The system has two replaceable fan modules and each module has six fans. The system allows failure of one fan out of 12 fans.
Max. number of disks	75
Disk type	NL-SAS
Backplane performance	12 Gbit/s

3.3.1 Expansion Module

The management plane of an expansion board manages power supplies, fans, and disks in the system. The service plane provides two 12 Gbit/s Mini SAS HD upstream links and two 12 Gbit/s Mini SAS HD downstream links through an SAS expander and writes data to and reads data from disks.

3.3.2 Indicator Introduction

After a disk enclosure is powered on, you can check the current operating status of the disk enclosure by viewing its indicators.

Indicators on the front panel

The following figure shows the indicators on the front panel of a disk enclosure.

Figure 3-9 High-density disk enclosure front-panel indicators

1	Location indicator of a high-density disk enclosure	2	Alarm indicator of a high-density disk enclosure
3	Power indicator of a high-density disk enclosure	4	Overtemperature indicator of a high-density disk enclosure
5	Status indicator of the internal module of a high-density disk enclosure	6	Alarm indicator of the rear module of a high-density disk enclosure

The following table describes the indicators on the front panel of a high-density disk enclosure.

Table 3-5 High-density disk enclosure front-panel indicator states and their meanings

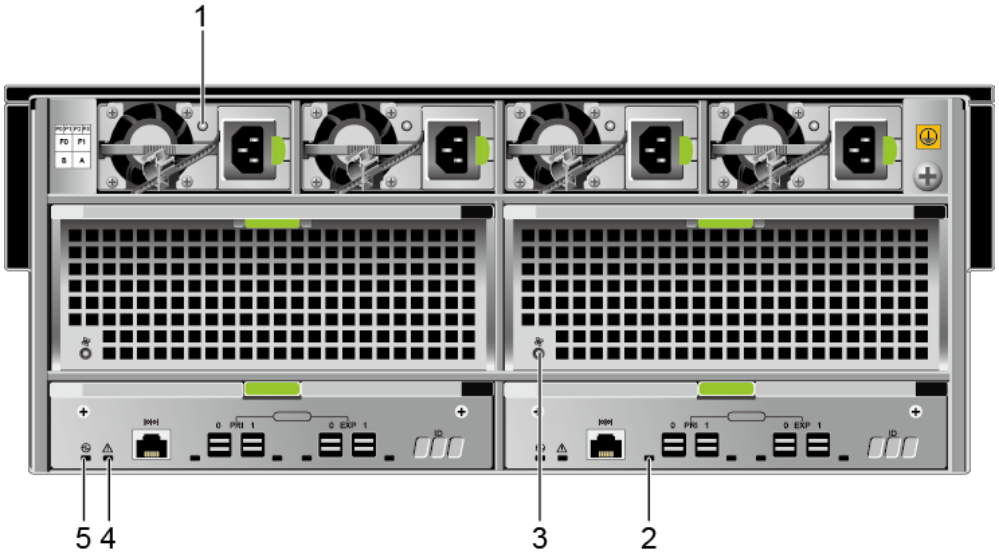
Module	No.	Indicator Type	Description
System enclosure	1	Location indicator of a high-density disk enclosure	• Blinking blue: The high-density disk enclosure is being located. • Off: The high-density disk enclosure is not located.
	2	Alarm indicator of a high-density disk enclosure	• Steady red: A high-density disk enclosure alarm is generated. • Off: The high-density disk enclosure is working correctly.
	3	Power indicator of a high-density disk enclosure	• Steady green: The high-density disk enclosure is powered on. • Off: The high-density disk enclosure is powered off.
	4	Overtemperature indicator of a high-density disk enclosure	• Steady red: The temperature of the high-density disk enclosure is too high. • Off: The temperature of the high-density disk enclosure is normal.
	5	Status indicator of the internal module of a high-density disk enclosure	• Steady red: A disk module in the high-density disk enclosure is faulty. • Blinking red: A disk module in the high-density disk enclosure is failing. • Off: The disk modules in the high-density disk

Module	No.	Indicator Type	Description
			enclosure are working correctly.
	6	Alarm indicator of the rear module of a high-density disk enclosure	• Steady red: The number of high-density disk enclosure rear FRUs is less than half of that in standard configuration, or rear FRUs are faulty. The rear FRUs of a high-density disk enclosure include power supplies, fan modules, and expansion modules. • Off: The high-density disk enclosure rear FRUs are working correctly.

3.3.3 Indicators on the Rear Panel

The following figure shows the indicators on the rear panel of a disk enclosure.

Figure 3-10 Indicators on the rear panel of a disk enclosure



1	Power supply running/alarm indicator	2	Mini SAS HD expansion port indicator
3	Fan module running/alarm indicator	4	Expansion module alarm indicator
5	Expansion module power indicator		

The following table describes the indicators on the rear panel of a disk enclosure.

Table 3-6 Description of the indicators on the rear panel of a disk enclosure

Module	No.	Indicator Type	Description
Power supply	1	Power supply running/alarm	• Steady green: The power supply is correct. • Blinking green: The power input is normal but the

Module	No.	Indicator Type	Description
		indicator	disk enclosure is powered off. • Steady red: The power supply is faulty. • Off: No external power is input.
Expansion module	2	Mini SAS HD expansion port indicator	• Steady blue: The link to the expansion port is up, and the data transfer rate is 4 x 6 Gbit/s. • Steady green: The link to the expansion port is up, and the data transfer rate is 4 x 3 Gbit/s. • Steady red: The port is faulty. • Off: The link to the expansion port is down.
Fan module	3	Fan module running/alarm indicator	• Steady green: The fan module is working correctly. • Steady red: The fan module is faulty. • Off: The fan module is powered off.
Expansion module	4	Expansion module alarm indicator	• Steady red: An expansion module alarm is generated. • Off: The expansion module is working correctly.
	5	Expansion module power indicator	• Steady green: The expansion module is working correctly. • Off: The expansion module is powered off.

4 Application

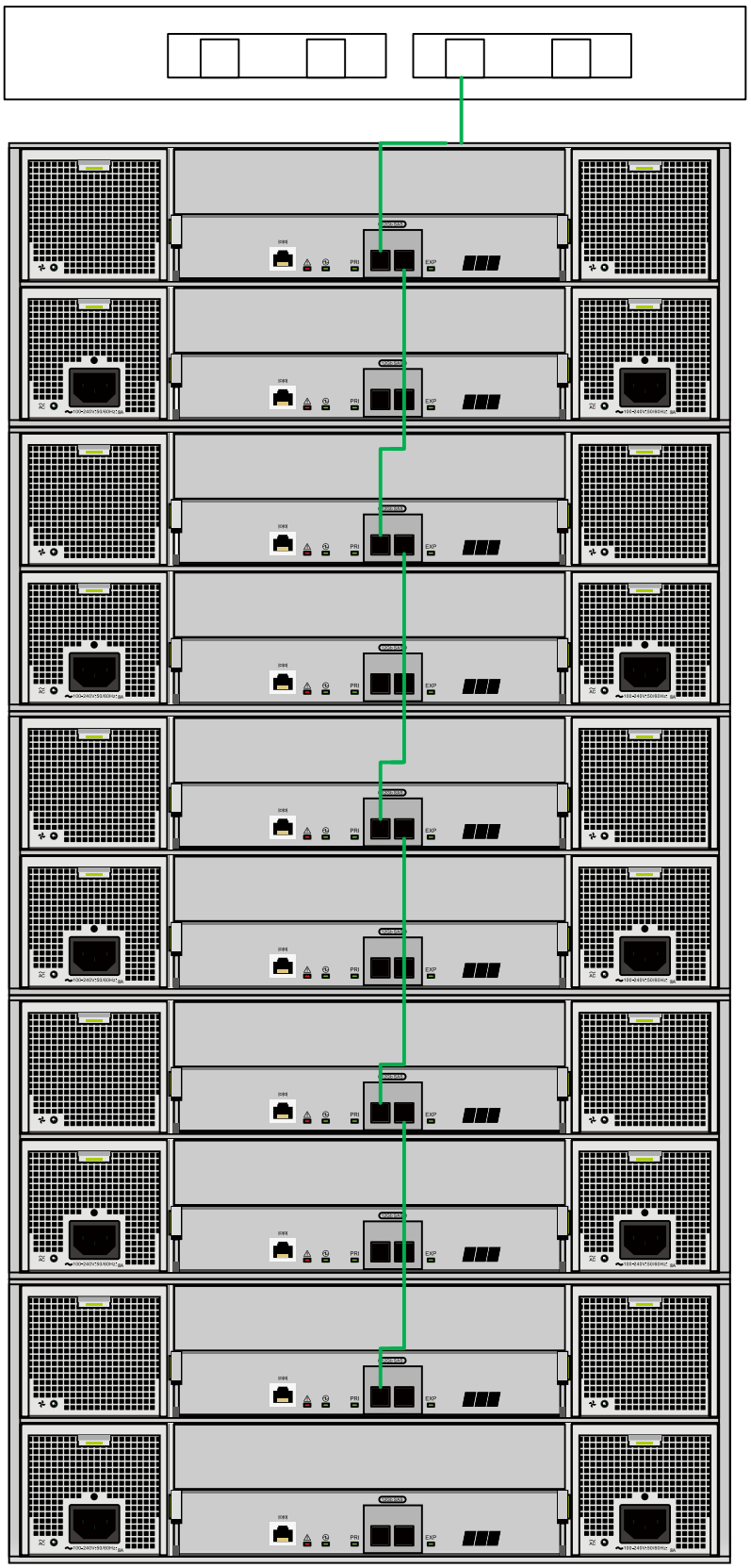
4.1 V3 DAS32435U4 Applications

4.1.1 Maximum Capacity Configuration for Single-link Networking

Descriptions about the networking are as follows:

- P0 on expansion modules of disk enclosures: upstream SAS ports
- P1 on expansion modules of disk enclosures: downstream SAS ports
- One link is configured between a server and a disk enclosure.

Figure 4-1 Single-link networking diagram



4.1.2 Single-link Networking in Forward and Backward Connections

Descriptions about the networking are as follows:

- Two servers are connected to high-density disk enclosures in forward and backward manners to provide optimal redundancy.
- P0 on expansion modules of disk enclosures: upstream SAS ports
- P1 on expansion modules of disk enclosures: downstream SAS ports
- Two servers are connected to controllers A and B of disk enclosures.
- Backward connections ensure access to the storage even when the server, cable, expansion module, or power supply is faulty.

Figure 4-2 Single-link networking in forward and backward connections

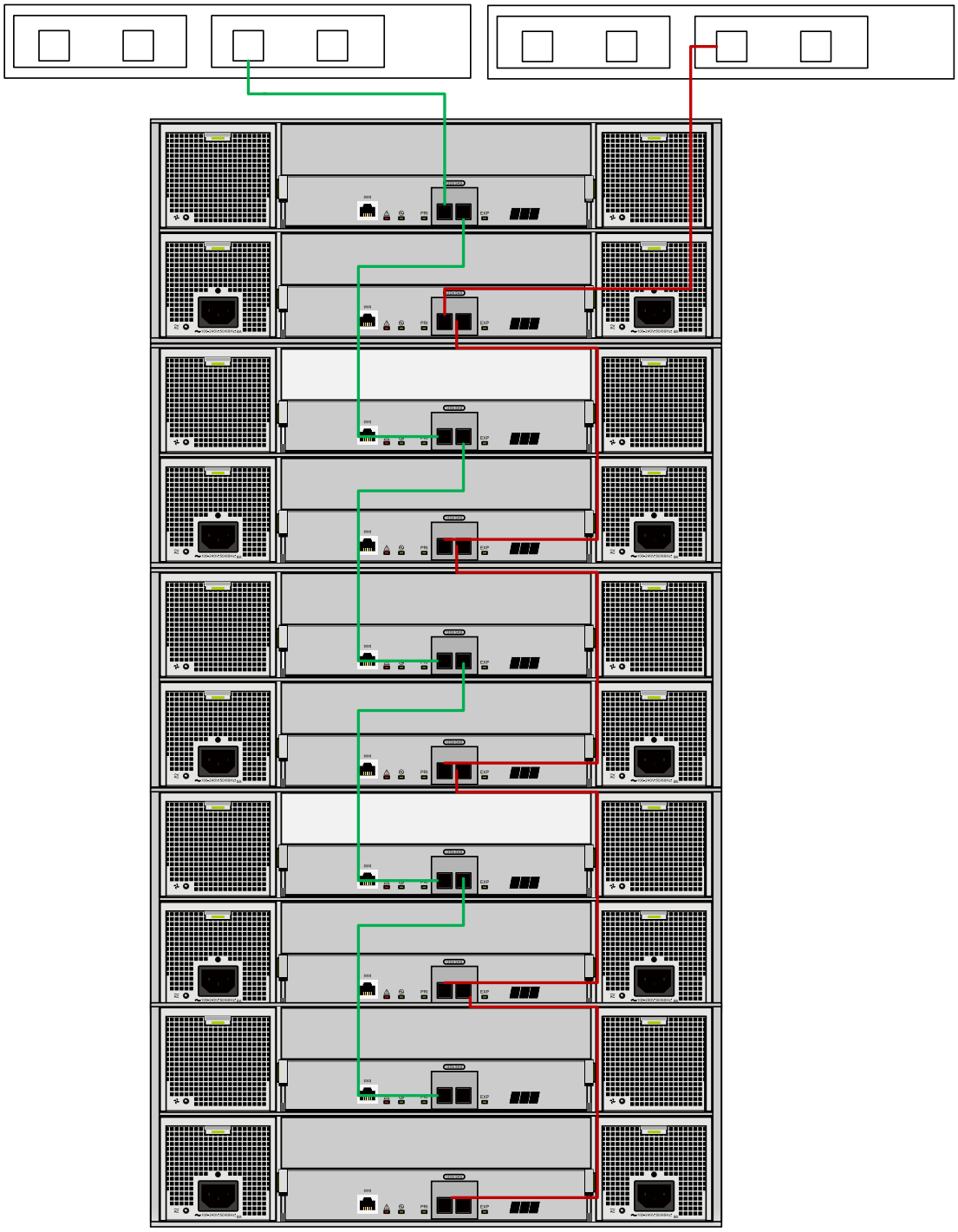
4.1.3 Single-link Redundant Networking in Forward Connections

Descriptions about the networking are as follows:

- Two servers are connected to disk enclosures in the forward manner with only one link to achieve optimal performance.

- P0 on expansion modules of disk enclosures: upstream SAS ports
- P1 on expansion modules of disk enclosures: downstream SAS ports
- Two servers are connected to controllers A and B of disk enclosures.
- Forward connection in symmetrical networking ensures access to the storage and reduces latency.

Figure 4-3 Single-link redundant networking in forward connections

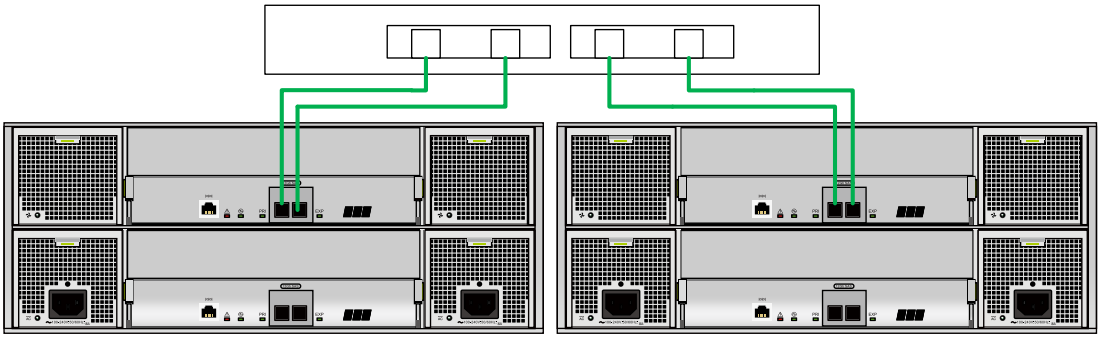


4.1.4 Dual-link Performance Networking

Descriptions about the networking are as follows:

- P0 on expansion modules of disk enclosures: upstream SAS ports
- P1 on expansion modules of disk enclosures: upstream SAS ports
- Two links are configured between a server and a disk enclosure.

Figure 4-4 Dual-link networking diagram

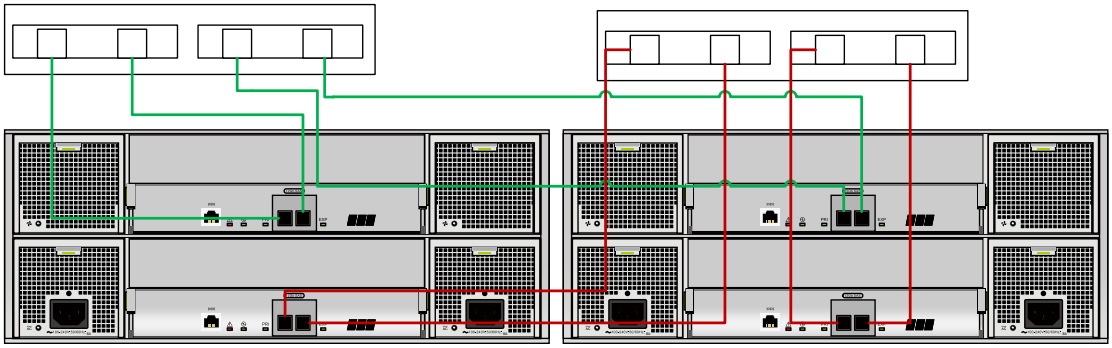


4.1.5 Dual-link Redundant Networking

Descriptions about the networking are as follows:

- P0 on expansion modules of disk enclosures: upstream SAS ports
- P1 on expansion modules of disk enclosures: downstream SAS ports
- Two links are configured between a server and a disk enclosure. The servers connect to controllers A and B of disk enclosures.

Figure 4-5 Dual-link redundant networking diagram



4.2 V3 DAS37535U4 Applications

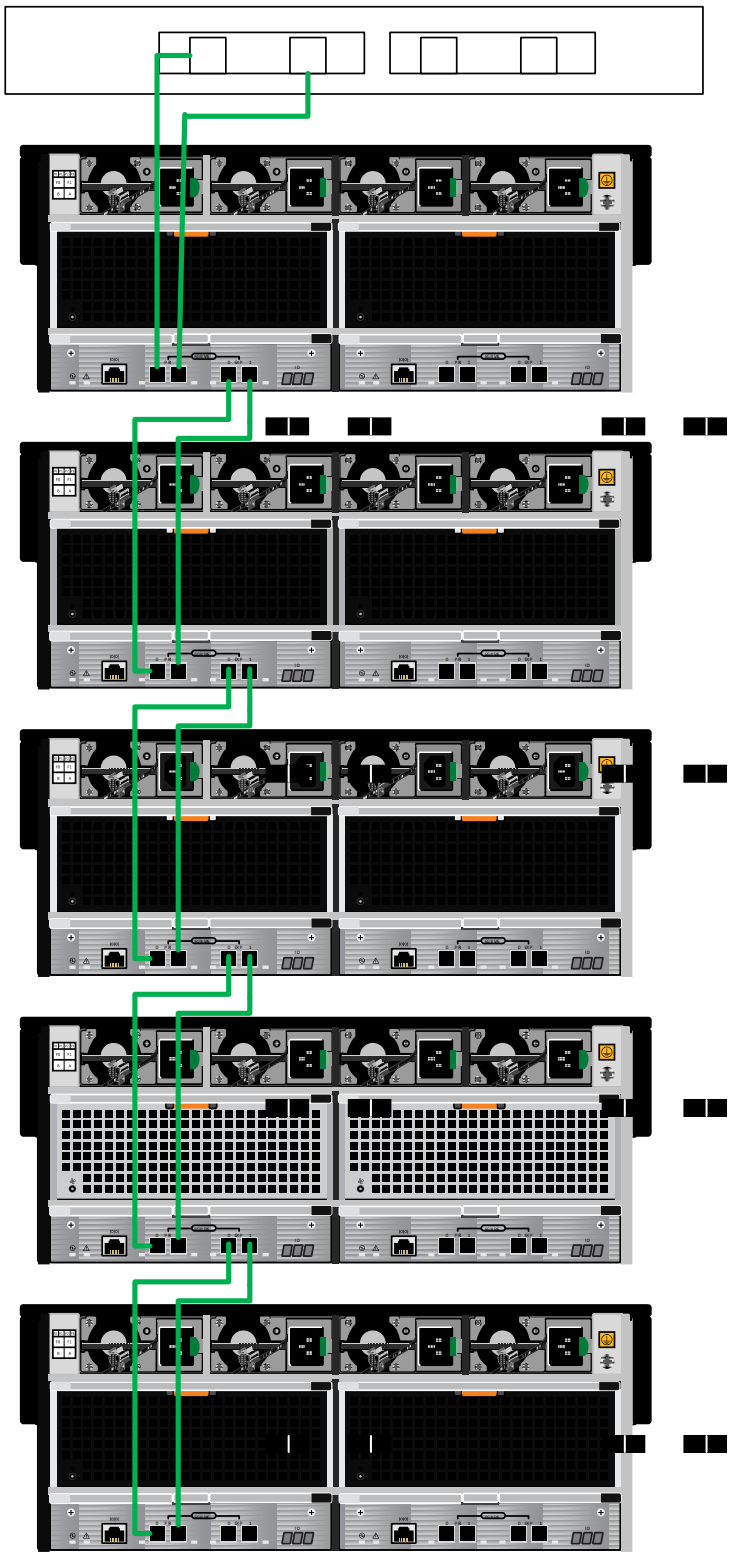
4.2.1 Maximum Capacity Configuration for Dual-link Networking

Descriptions about dual-link networking are as follows:

- PRI0 and PRI1 on expansion modules of disk enclosures: upstream SAS ports

- EXP0 and EXP1 on expansion modules of disk enclosures: downstream SAS ports
- Two links are configured between a server and a disk enclosure.

Figure 4-6 Dual-link networking diagram



4.2.2 Dual-link Redundant Networking in Forward and Backward Connections

Descriptions about the networking are as follows:

- Two servers are connected to high-density disk enclosures in forward and backward manners to provide optimal redundancy.
- PRI0 and PRI1 on expansion modules of disk enclosures: upstream SAS ports
- EXP0 and EXP1 on expansion modules of disk enclosures: downstream SAS ports
- Two servers are connected to controllers A and B of disk enclosures.
- Backward connections ensure access to the storage even when the server, cable, expansion module, or power supply is faulty.

NOTE

1. The following is an example of DAS connection. The number of connected DAS storage systems depends on the drive capability of an HBA's SAS chip.
2. A 5 m SAS cable connects one disk enclosure to another one in forward and backward connections in a cabinet (a maximum of four cascaded disk enclosures).
3. Cables cannot be routed on the top of a cabinet or on the floor that is under a cabinet. Cables can only be routed across cabinets through the middle part of a cabinet after you remove the side panels, as shown in Figure 4-8

Figure 4-7 Dual-link redundant networking in forward and backward connections

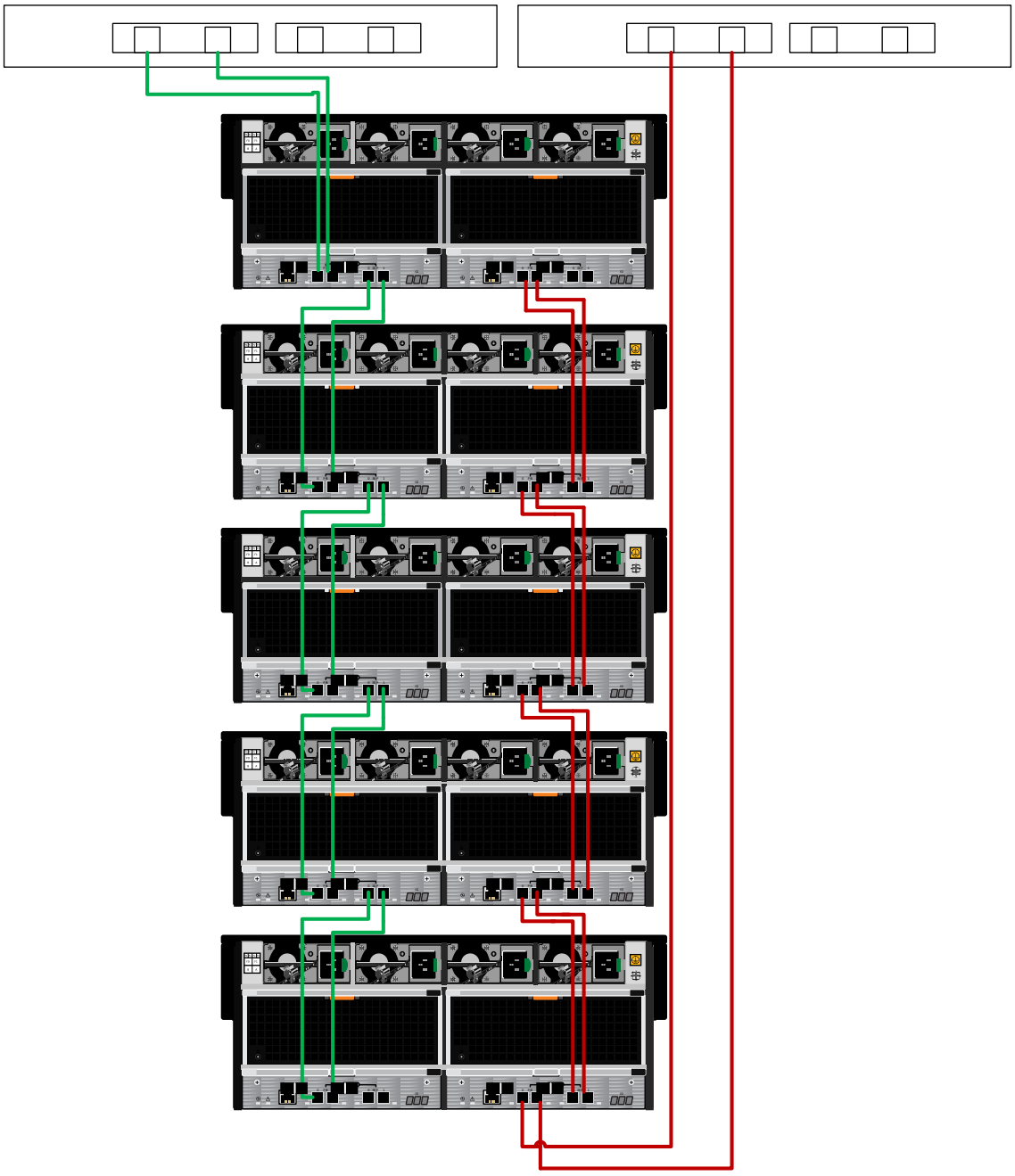
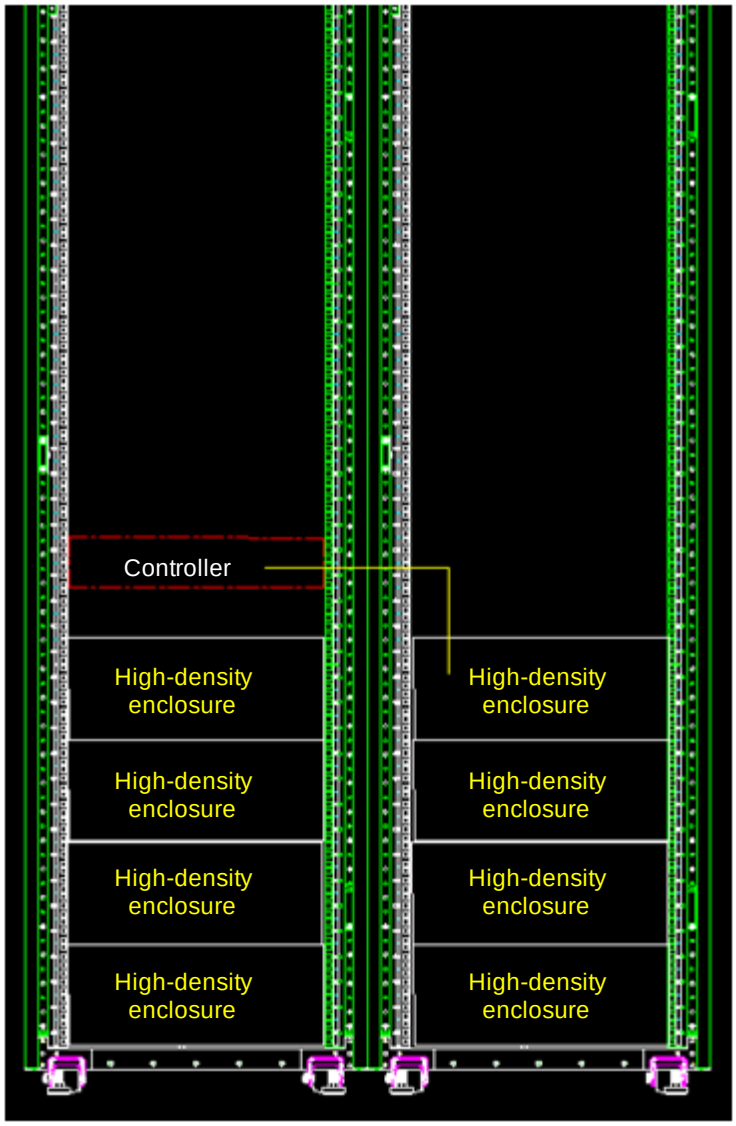


Figure 4-8 Cross-cabinet routing



4.2.3 Dual-link Redundant Networking in Forward Connections

Descriptions about the networking are as follows:

- Two servers are connected to disk enclosures in the forward manner with two links to achieve optimal performance.
- PRI0 and PRI1 on expansion modules of disk enclosures: upstream SAS ports
- EXP0 and EXP1 on expansion modules of disk enclosures: downstream SAS ports
- Two servers are connected to controllers A and B of disk enclosures.
- Forward connection in symmetrical networking ensures access to the storage and reduces latency.

Figure 4-9 Dual-link redundant networking in forward connections

4.3 Restrictions on Networking

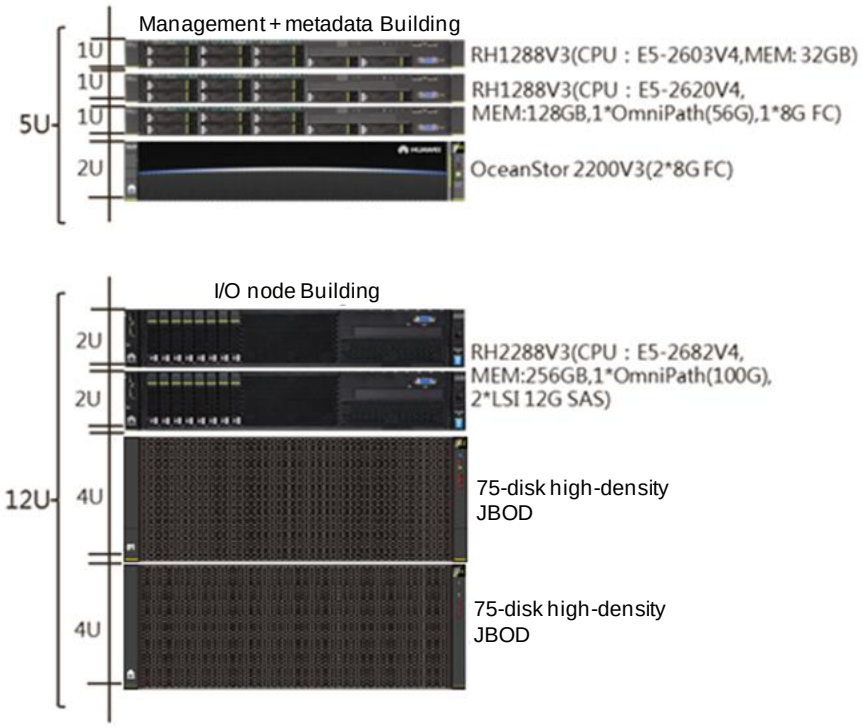
4.3.1 Zoning Restrictions on SAS-based DAS

1. Different zoning groups cannot be connected to the same server.
2. Cascading is not supported after zoning of SAS-based DAS.

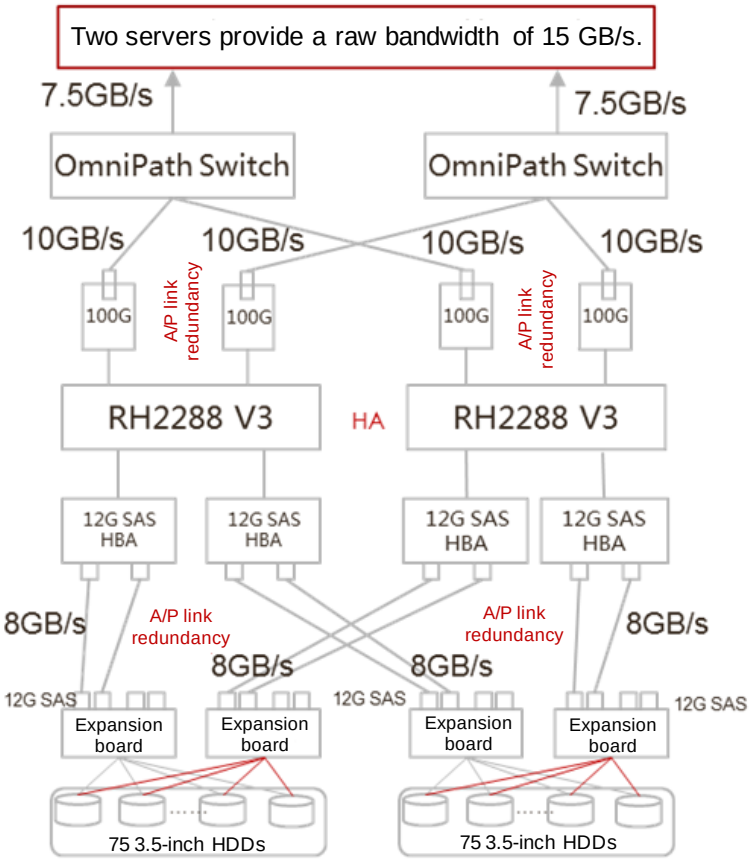
5 (Optional) Application Examples

A DAS-based HPC storage solution

5.1 Networking



Note: Bandwidths in this figure are estimated values for the test.



6 Reference

1. Document name + author + date + source
2. Document name + author + date + source