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IBM FlashSystem A9000R Product Guide

(Updated for Version 12.3.2)

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Product Guide

IBM FlashSystem A9000R Product Guide

This IBM® Redbooks® Product Guide is an overview of the main characteristics, features, and technology that are used in IBM FlashSystem® A9000R Models 425 and 25U, with IBM FlashSystem A9000R Software V12.3.2.

IBM FlashSystem A9000R is a grid-scale, all-flash storage platform designed for industry leaders with rapidly growing cloud storage and mixed workload environments to help drive your business into the cognitive era. FlashSystem A9000R provides consistent, extreme performance for dynamic data at scale, integrating the microsecond latency and high availability of IBM FlashCore® technology. The rack-based offering comes integrated with the world-class software features that are built with IBM Spectrum™ Accelerate. For example, comprehensive data reduction, including inline pattern removal, data deduplication, and compression, helps lower total cost of ownership (TCO) while the grid architecture and IBM Hyper-Scale framework simplify and automate storage administration.

Ready for the cloud and well-suited for large deployments, FlashSystem A9000R delivers predictable high performance and ultra-low latency, even under heavy workloads with full data reduction enabled. As a result, the grid-scale architecture maintains this performance by automatically self-optimizing workloads across all storage resources without manual intervention. As shown in Figure 1, FlashSystem A9000R Model 425, installed in a T42 rack, offers capacity-optimized configurations that are cost-competitive with hybrid storage system.

Figure 1 Front view of FlashSystem A9000R Model 425 and T42 rack

FlashSystem A9000R Model 425 can scale up to 3.6 PetaBytes in a single rack.

Note: In June of 2018, IBM withdrew all four versions of the Model 415. They can no longer be ordered or purchased, but existing A9000R model 415 systems can continue to be upgraded with additional grid elements.

FlashSystem A9000R provides a scale-up building block approach to growth. Each 6U building block, called a *grid element*, contains two grid controllers for cache, compute, and interface capabilities, and an IBM flash enclosure for data storage.

Key capabilities: FlashSystem A9000R includes the following capabilities for optimal solution in a cloud environment:

- FlashCore technology provides extreme IBM MicroLatency® performance.
- Grid Architecture ensures consistent and predictable microsecond response times.
- An enhanced management interface simplifies storage administration.
- Rich integrated data services provide peace of mind and includes data-at-rest encryption
- IBM Hyper-Scale provides simple scaling and management.
- Quality of service (QoS) and Multi-tenancy with network traffic isolation through VLAN support
- Data reduction and intelligent capacity management for deduplication optimizes your infrastructure economics.
- High availability and disaster recovery features
- Key integration capabilities allow for systems to fit into and support your environment.

Storage Utility Offering

As of March 2018, along with software version 12.2.1 or later, IBM FlashSystem A9000R (9837-U25) storage utility model is available as part of the IBM Storage Utility Offering. Model U25 is otherwise identical to Model 425.

The storage utility model provides a fixed total capacity, with a base and variable usage subscription of that total capacity. The variable capacity usage is billed on a quarterly basis.

IBM Storage Utility Offering allows clients to align their capacity costs to business initiatives. For details, see the IBM Storage Utility Offering home page:

https://www.ibm.com/us-en/marketplace/storage-utility-offering

FlashSystem A9000R entry level capacity option

Beginning with Version 12.3, there is an option to start with a smaller entry-level configuration, called *the Grid-Starter* in this publication. This option takes the three capacity points allowed for the A9000R, and removes one grid controller and one flash enclosure. Put another way, it is an A9000 (except for the partially populated FS 900 entry configuration) put into a rack with the InfiniBand switches.

Starting with software version 12.3.1, this entry-level configuration can be nondisruptively upgraded by adding flash enclosures and grid controllers as required by the target configuration to scale out system capacity and performance. Scale out from the entry point configuration supports target configurations of two, three, and four flash enclosures with four, six, and eight grid controllers, respectively.

Important: It is not possible, nor supported to convert an installed FlashSystem A9000 system to a FlashSystem A9000R entry level system.

Product highlights

FlashSystem A9000R provides an all-inclusive software license. All features, including replication, migration, encryption, and data reduction, are included at no extra charge with FlashSystem A9000R Software V12 (5639-FS1), and apply to the entire storage system. The following features are also included:

- Data reduction: Pattern removal, data deduplication, and compression

  FlashSystem A9000R uses the IBM industry-leading data reduction technology that combines inline, real-time pattern matching and removal, data deduplication, and compression. Compression also uses hardware cards inside each grid controller.

  Compression can easily provide a 2:1 data reduction saving rate on its own, which effectively doubles the system storage capacity. Combined with pattern removal and data deduplication services, FlashSystem A9000R can yield an effective data capacity of five times the original usable physical capacity.

  Data reduction is implemented below the global cache to ensure rapid response times. This configuration provides a global scope for data reduction services, and enables other data services to be unaffected, including snapshots, replication, and host offload features, such as VMware vStorage API for Array Integration (VAAI).

- Intelligent capacity management for deduplication:

  Starting with software version 12.3.1, FlashSystem A9000 and A9000R offers patented IBM Research technology that can analyze large amounts of data, without performance impact and provide effective estimates, per volume, for reclaimable capacity, attributed capacity, compression saving, de-duplication saving, and total capacity saving. That information is displayed in the Hyper-Scale Manager GUI (version 5.5.1 minimum is required).

- Multi-tenancy

  FlashSystem A9000R enables a secure isolation of logical domains of storage resources among numerous tenants, with the ability to set different QoS levels for each domain. Multi-tenancy enables the division of storage system administration tasks into logical domains by using role-based permissions. It also enables rapid deployments while minimizing the need for extensive planning, tuning, or field upgrades.

- VLAN tagging and port trunking

  Starting with software version 12.3.2, support for VLANs in iSCSI environments allows provisionning of private virtual network per tenant. FlashSystem A9000R VLAN support applies to the data iSCSI ports for hosts and replication, as well as management ports and other Ethernet ports. VLAN support capabilities include VLAN tagging and port trunking as defined by the IEEE 802.1Q specification. Hyper-Scale Manager GUI, version 5.6 or later is required. For more information, refer to Chapter 2 in *IBM FlashSystem A9000/R and IBM XIV Storage System Host Attachment and Interoperability*, SG24-8368.

- Host Rate Limiting: QoS

  FlashSystem A9000R system resources, such as storage and cache, constitute a virtualized environment that is shared by all hosts and applications. This approach is exceptionally appropriate to accommodate high-performance requirements for multiple applications with similar performance objectives through fair resource allocation. QoS is available at the domain, pool, and volume levels.

  In environments with applications that include various performance objectives, the QoS feature enables the client to restrict IOPs, bandwidth, or both to the appropriate object domain, pool, host group, or volume. QoS can be used to ensure that applications

do not use too much of the storage system resources, which maximizes the resources that are available for applications that require the utmost performance.

- Fibre Channel and iSCSI

  FlashSystem A9000R supports the Fibre Channel and iSCSI communications protocols for host attachment, migration, and remote mirroring. Newer systems have grid controllers equipped with FC-NVMe adapters. In these new controllers, the FC ports are dual-purposed and NVMe ready: a future software upgrade will enable these ports to connect with servers using FC, or using FC-NVMe, or both.

- Snapshots

  The snapshot capabilities use a redirect on write design that allows snapshots to occur in a subsecond time frame with no effect on performance. The system supports multiple differential snapshots of a volume. Any of the snapshots can be made writable. Snapshots can then be taken of the newly writable snapshots (snapshots of snapshots). Volumes can even be restored from these writable snapshots. The built-in Snapshot Scheduler allows you to automate the snapshot creation and retention on volumes inside a specific pool.

- Synchronous remote mirroring to another FlashSystem A9000 or A9000R and asynchronous remote mirroring to another FlashSystem A9000, A9000R, or IBM XIV® Gen3.

  Synchronous or asynchronous remote mirroring can be performed over Fibre Channel (FC) or IP (iSCSI) connections. Both protocols also are supported for two-way mirroring connectivity. Synchronous remote mirroring is used when a zero recovery point objective (RPO) is required. For practical reasons (latency), ensure that the distance is less than 100 km (62 miles). For longer distances, asynchronous replication is more appropriate.

  Starting with FlashSystem A9000R Software V12.2.1, up to 3072 sync mirrors and up to 1024 async mirrors are supported. The maximum number of remote targets is 10.

- IBM HyperSwap®

  HyperSwap, also referred to as *transparent failover*, delivers always-on, high availability (HA) service for storage volumes in a production environment. It is based on an active-active, cross-system, and cross-datacenter configuration, allowing volumes to autonomously and transparently switch between primary and secondary roles, based on the volume failover state. From a host perspective, the pair of mirrored volumes on the two FlashSystem A9000 or A9000R systems constitute a *single HyperSwap volume*, also referred to as a *stretched volume*, enabling the seamless failover.

- Multi-site HA/DR replication

  Using three FlashSystem A9000 or A9000Rs, and combining HyperSwap and Asynchronous replication, creates a solution that entails both high availability (HA) and disaster recovery (DR). One side of the HyperSwap pair has an active asynchronous link to the third box, and the other side has a standby link. For more information about multisite replication, see *IBM HyperSwap and Multi-site HA/DR for IBM FlashSystem A9000 and A9000R*, REDP-5434.

- Data Migration

  FlashSystem A9000R also can act as a host and gain access to volumes on a storage system. The system is configured as a proxy to respond to requests between the current hosts and the storage while migrating all data in the background.

- Hyper-Scale Mobility

  IBM Hyper-Scale Mobility allows a volume to be migrated non-disruptively from one FlashSystem A9000R to another FlashSystem A9000 or A9000R over synchronous WAN distances without any host disruption. This capability is in addition to the standard data

migration that allows FlashSystem A9000R to proxy as a host and migrate volumes from other third-party storage arrays.

Starting with Software Version 12.2.1, Hyper-Scale Mobility is also supported from XIV Gen3 (with software level 11.6.2a or later) to FlashSystem A9000 or A9000R.

For more information about replication and migration, see the IBM Redbooks publication, *IBM FlashSystem A9000 and A9000R Business Continuity Solutions*, REDP-5401.

- Encryption

  FlashSystem A9000R secures all written data with industry-standard AES-256 encryption for data-at-rest. It protects the grid controller SSDs and flash enclosure MicroLatency modules against exposure of sensitive data on discarded or stolen media by ensuring that the data cannot be read if the key used to encrypt the data is secured.

  Encryption is carried out at the hardware level to avoid any performance impact. Encryption key management can be carried out through an external or a local key scheme. For more information, see the IBM Redbooks publication, *Data-at-rest Encryption for the IBM Spectrum Accelerate Family*, REDP-5402.

- Authentication by using Lightweight Directory Access Protocol (LDAP)

  LDAP can be used to provide user logon authentication, which allows FlashSystem A9000R to integrate with Microsoft Active Directory, Open LDAP, and Oracle Java Systems Directory Server. Multiple directory servers can be configured to provide redundancy if one server becomes unavailable.

  For more information, see the IBM Redbooks publication, *Enabling LDAP for IBM FlashSystem A9000 and A9000R with Microsoft Active Directory*, REDP-5387.

- OpenStack and REST support

  FlashSystem A9000R can use the well-established IBM code base for OpenStack and REST API support.

  For more information, see the IBM Redbooks publication, *Using XIV in OpenStack Environments*, REDP-4971.

- VMware synergy

  IBM Spectrum Control™ Base V3.0 enables a simplified deployment and efficient integration of FlashSystem A9000R with the VMware vCloud suite.

  See the IBM Redbooks publication, *Using the IBM Spectrum Accelerate Family in VMware Environments: IBM XIV, IBM FlashSystem A9000 and IBM FlashSystem A9000R, and IBM Spectrum Accelerate*, REDP-5425.

- Cloud integration

  FlashSystem A9000 integrates easily into your existing data center infrastructure. It also integrates with a wide variety of cloud environments, including solutions for Kubernetes container environments, in addition to IBM Cloud™ Private, VMware, OpenStack, and Microsoft environments, at no additional cost.

- Container support

  IBM Spectrum Connect enables the use of persistent storage for containers in Kubernetes environments. See the IBM Redbooks publication, *IBM Spectrum Connect and IBM Storage Enabler for Containers: Practical Example with IBM FlashSystem A9000*, REDP-5470.

Hardware architecture

FlashSystem A9000R uses a grid-based architecture that delivers performance while allowing for ease of use. Data placement is determined by the system, which frees the operator to concentrate on other aspects of their daily tasks. There are two main component types: The grid controller and the flash enclosure.

Two grid controllers and one flash enclosure are combined to make one grid element. FlashSystem A9000R Model 425 consists of 2 - 4 grid elements. Adding grid elements increases the capacity, caching, and processing power of the FlashSystem A9000R.

FlashSystem A9000R rack

FlashSystem A9000R is delivered in a standard IBM T42 rack.

FlashSystem A9000R Model 425 can be ordered with up to four grid elements that contain eight grid controllers and four flash enclosures. Figure 2 shows a front view of a fully equipped FlashSystem A9000R Model 425 when the rack door is opened.

Figure 2 FlashSystem A9000R Model 425 full rack view (front door open)

FlashSystem A9000R comes preconfigured according to the ordered configuration. All grid elements are preinstalled in the rack with all interconnection cables in place. The two InfiniBand switches, two power distribution units (PDUs), and a management patch panel are installed in the middle of the rack. All components are connected through two redundant 56 GB Fourteen Data Rate (FDR) Mellanox InfiniBand switches.

Grid controller

The grid controller handles the compute-intensive portion of the workload and enforces data distribution to ensure that all of the resources of the system are being used. The grid controller also handles I/O from the attached hosts by providing 16 Gb FC ports and 10 Gb iSCSI ports.

FC-NVMe ready adapter: Model 425, shipping with Software Version 12.2.1or later, contain enhanced grid controllers equipped with FC-NVMe ready adapters. In these new controllers, the FC ports are dual-purpose and NVMe ready. IBM plans[a] a future software upgrade that will enable these ports to connect with servers using FC, or using FC-NVMe, or both.

a. IBM's statements regarding its plans, directions, and intent are subject to change or withdrawal without notice at IBM's sole discretion. Information regarding potential future products is intended to outline our general product direction and it should not be relied on in making a purchasing decision. The information mentioned regarding potential future products is not a commitment or legal obligation to deliver any material, code, or functionality.

The grid controller is an Intel Xeon processor-based, reliable, high-end server. It offers two CPU sockets, 24 DDR4 ECC capable memory slots, and high-speed PCI Express 3.0 connectors to attach and serve all I/O ports that are required for FlashSystem A9000R.

Table 1 lists internal hardware components that are contained in the grid controller for FlashSystem A9000R Model 425.

Note: In June of 2018, IBM withdrew all four versions of the Model 415. They can no longer be ordered or purchased, but existing A9000R model 415 systems can continue to be upgraded with additional grid elements.

Table 1 Grid controller components in FlashSystem A9000R Model 425

Component	Description
Processor	2 Intel E5-2650 v4 @ 2.20 GHz 12 Cores with Hyper Threading
Memory	384 GB DDR4 RAM
InfiniBand adapter	1 Mellanox InfiniBand Connect Dual Port 56 Gbps FDR
16 Gb Fibre Channel adapter	0 or 2 QLogic QLE2962 Dual Ports (earlier machines might have QLE2662 instead)
10 Gb Ethernet adapter	1 or 2 Mellanox ConnectX-3 Pro Dual Port
Compression Accelerator	2 Intel Coleto Creek cards
Hard disk drive	2 hot-swap, RAID1 HDDs for system firmware and logging
Solid-state disks	2 hot-swap, 400 GB SSDs as vault devices
Battery Module	Dual internal redundant battery backup units.

Figure 3 shows the front view of the grid controller. The drive cage contains two hard disks in a RAID 1 that are the grid controller boot devices, holding FlashSystem A9000R microcode and various system logs and events. In the two rightmost slots of the drive cage are two SSDs that are used as vault devices for cache and metadata. In the middle of the controller are two battery backup units.

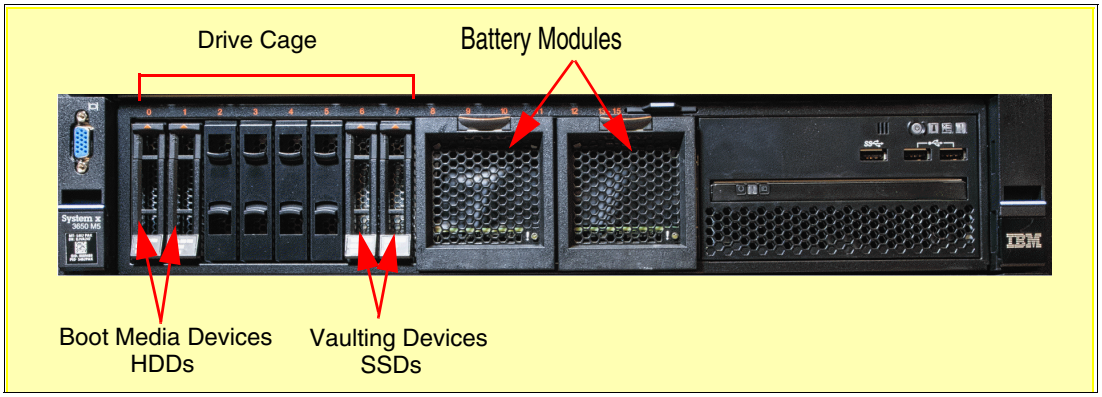

Figure 3 Grid controller front view

By design in FlashSystem A9000R, the grid controller is an isolated failure domain. As such, any failure or maintenance action that requires shutting down one grid controller does not affect the overall system. Figure 4 shows the rear view of a grid controller.

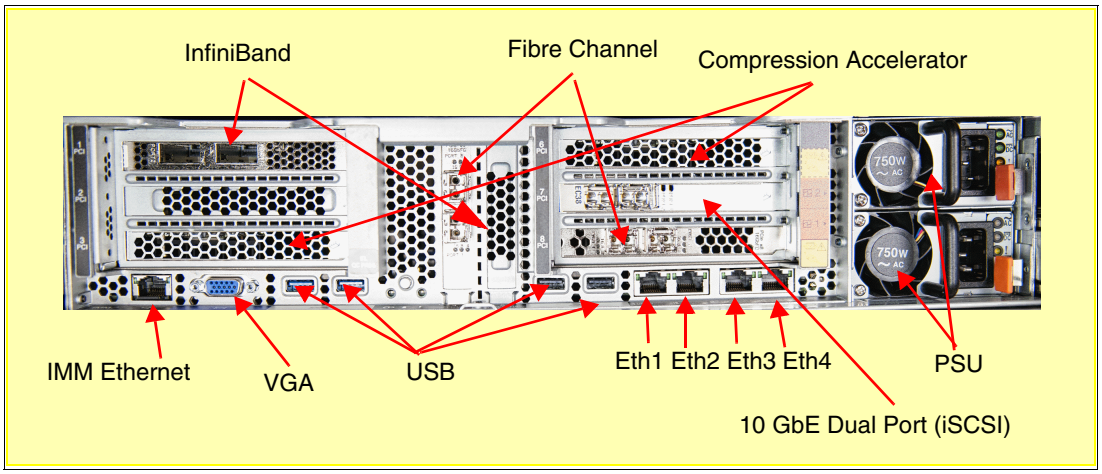

Figure 4 Grid controller rear view for FlashSystem A9000R

The rear of the controller includes the following components:

- The PCI slots on the left side of the controller contain one dual port InfiniBand adapter in the top slot and one of the compression accelerators in the bottom slot.
- At the bottom of the controller is an Ethernet port that can access the integrated management module (IMM). This Ethernet port is not used in FlashSystem A9000R.
- Next to the Ethernet port is a VGA connector and four USB ports. In some configurations, the USB ports are used for the maintenance daisy chain, or as VPN management Ethernet ports that use an adapter.
- The vertical PCI slots in the middle contain another InfiniBand card, which can contain an FC (or FC-NVMe) adapter.

- The top PCI slot on the right side of the controller contains the second compression accelerator card. In the middle slot is a 10 GbE dual port adapter. The bottom slot can contain an FC or FC-NVMe adapter, or an extra 10 GbE adapter.
- Below the PCI slots are four 1 GB Ethernet adapters that are used for the internal communication and as management ports.
- On the right side are two power supplies.

InfiniBand connection between the grid controllers is used for data transfer and internal management purposes. Management task uses IP over InfiniBand (IPoIB) for concurrent code upgrade, connectivity status checks, and so on.

Although two options are available for the grid controllers in FlashSystem A9000R, all grid controllers in any single FlashSystem A9000R must be of the same option, as described next.

FC and iSCSI option

Figure 5 shows the FC option of the grid controller, which includes the following components:

- One dual port 10 GbE controller in the middle right PCI slot (highlighted in green in Figure 5) for iSCSI connectivity.
- One dual port FC-NVMe adapter in the middle and another FC-NVMe adapter at the lower right (highlighted in yellow in Figure 5).

The blue rectangle in Figure 5 highlights the InfiniBand adapter that is used for the internal backend communication only. The InfiniBand card cannot be used for host or mirroring access.

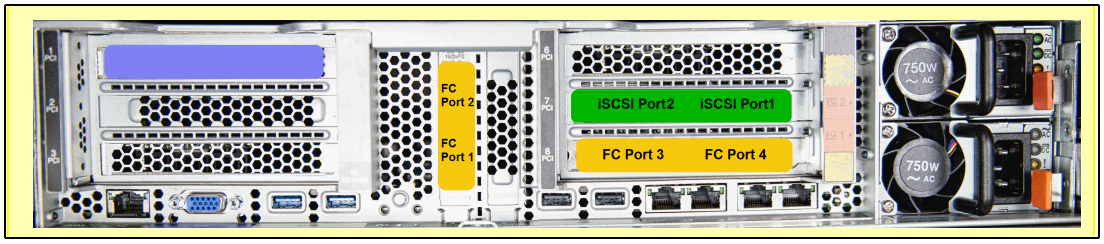

Figure 5 Fibre Channel with iSCSI option

iSCSI only option

Figure 6 shows the grid controller with the dual iSCSI connection option. It contains one 10 GbE dual port adapter in the middle right and a similar adapter in the lower right, both for iSCSI connectivity (highlighted in green in Figure 6).

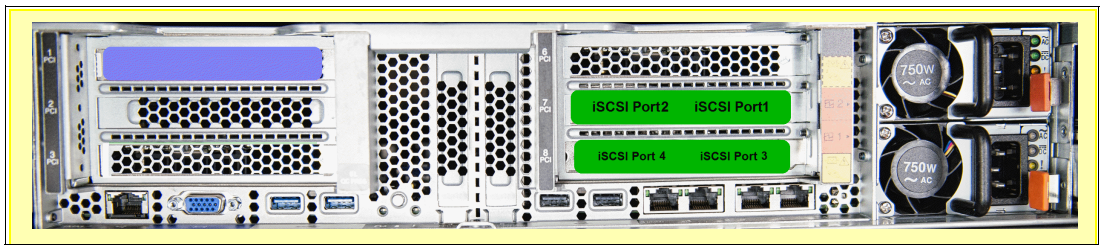

Figure 6 iSCSI only option

Flash enclosure

FlashSystem A9000R Model 425 includes improved flash enclosures, with larger and more flexible capacity points, achieved by combining three-dimensional (3D) chip layout with triple-level cell (TLC) transistors. The enclosure also offers inline always-on hardware compression that is done correctly on the MicroLatency modules without any performance impact.

FlashSystem A9000R continues to implement a full data reduction engine, including pattern removal, data deduplication, and compression in the grid controllers to achieve up to a 5x compression ratio. However, to reduce CPU workload and improve performance, internal metadata is not compressed by the grid controllers, allowing the underlying MicroLatency modules to do it instead.

Each flash enclosure includes 12 flash modules (MicroLatency modules), battery modules, power supplies, and two fully redundant canisters, as shown in Figure 7.

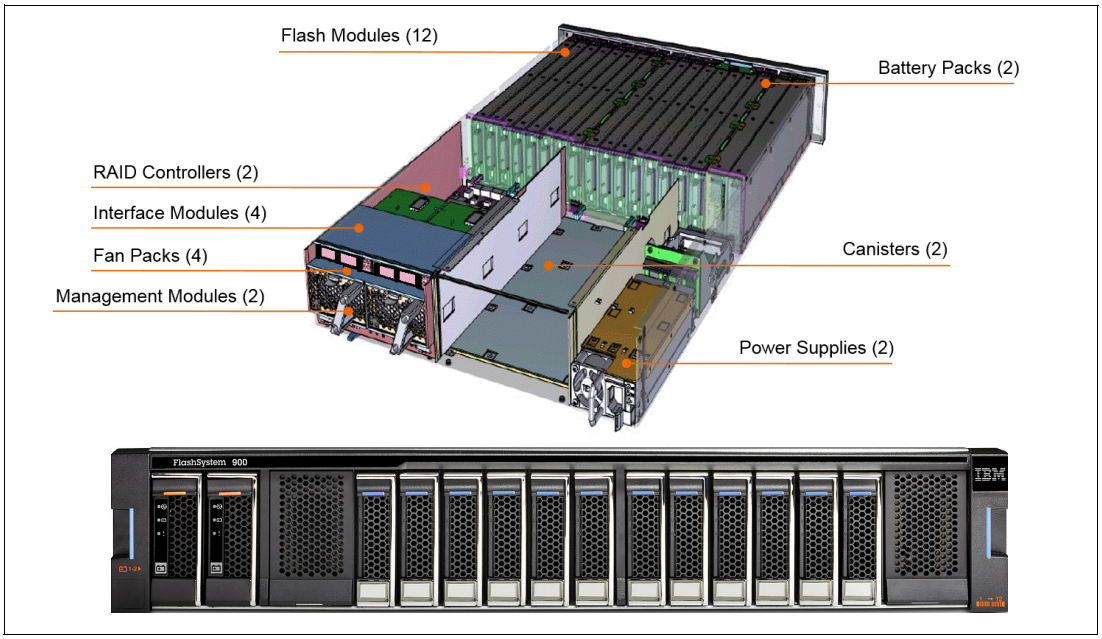

Figure 7 Flash enclosure inside view and front view (Model 425)

Each flash enclosure canister contains the RAID controllers, interface modules, management module, two hot-swappable fan modules, two Ethernet ports, and two USB ports. The two interface controllers are at the top of the container, and each has two 40 Gbps InfiniBand ports.

The flash enclosure contains 12 equally sized MicroLatency Modules. Model 425 has three options for the MicroLatency module capacity: 3.6 TB, 8.5 TB, and 18 TB. The data reduction technology allows each flash enclosure to offer effective capacities of 180 TB, 425 TB, and 900 TB, which assumes a data reduction saving ratio of 5:1.

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Note: The capacity of all MicroLatency modules across all grid elements in FlashSystem A9000R must be the same.

FlashSystem A9000R switched InfiniBand

An InfiniBand connection between grid controllers and flash enclosures is used for data transfer only.

As shown in Figure 4 on page 8, each grid controller has an InfiniBand HCA with two ports that is cabled to each of the two InfiniBand switches. Each flash enclosure has four interface cards with two InfiniBand ports. The first port of every flash enclosure interface is attached to a switch so that every flash controller canister is attached to both switches. The switches are also linked to each other.

Each InfiniBand switch contains 36 ports that support InfiniBand FDR. An FDR supporting port has four lanes that run a bit rate of 14 Gbps, which results in an effective bandwidth of more than 56 Gbps full bidirectional bandwidth per port. Port-to-port latency is less than 200 nanoseconds.

Figure 8 shows the cabling for FlashSystem A9000R with four grid controllers and two flash enclosures. In Figure 8, the switch #1 InfiniBand network is yellow, the switch #2 InfiniBand network is red, and the switch interconnect is black.

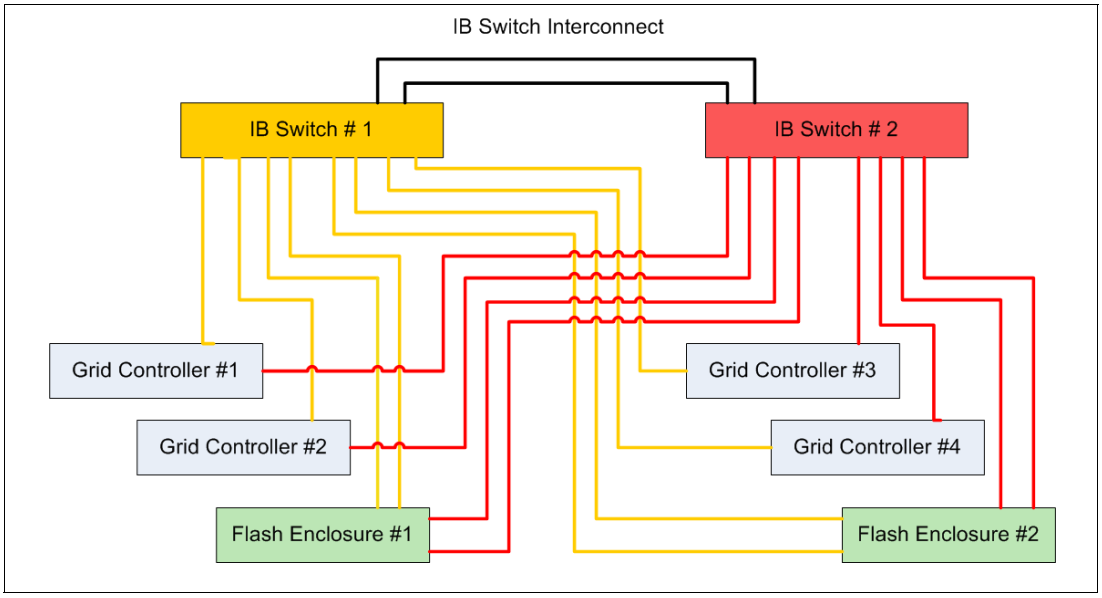

Figure 8 FlashSystem A9000R InfiniBand cabling

Figure 9 shows the rear view of a flash enclosure with InfiniBand cabling. The yellow and red cabling reflects the two InfiniBand networks, as shown in Figure 8.

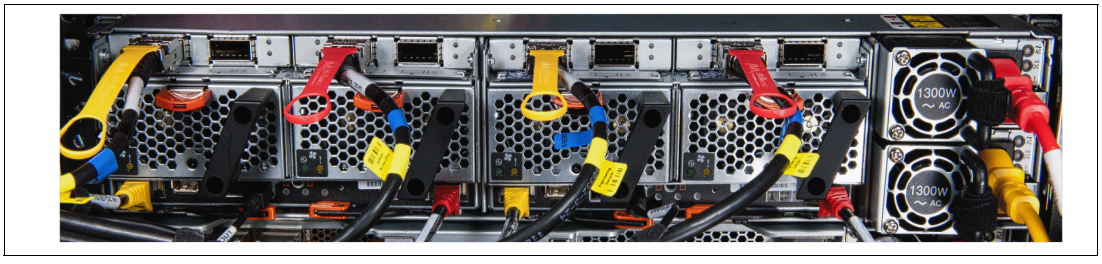

Figure 9 Flash enclosure rear view with InfiniBand data cabling

FlashSystem A9000R scalability

Any flash enclosure in IBM Flash System A9000R is populated with 12 MicroLatency Modules. The models have these capacity options: 3.6 TB, 8.5 TB, and 18 TB.

Note: The size of all MicroLatency modules in one FlashSystem A9000R must be equal and cannot be changed later.

Figure 10 shows possible scaling options for FlashSystem A9000R. The minimum configuration, which is shown on the left, is the entry-level configuration. The entry-level configuration is only valid for a Model 425. A fully configured rack contains four grid elements. Starting with software version 12.3.1, this entry-level configuration can be nondisruptively upgraded by adding flash enclosures and grid controllers as required by the target configuration to scale out system capacity and performance. Scale out from the entry point configuration supports target configurations of two, three, and four flash enclosures with four, six, and eight grid controllers, respectively.

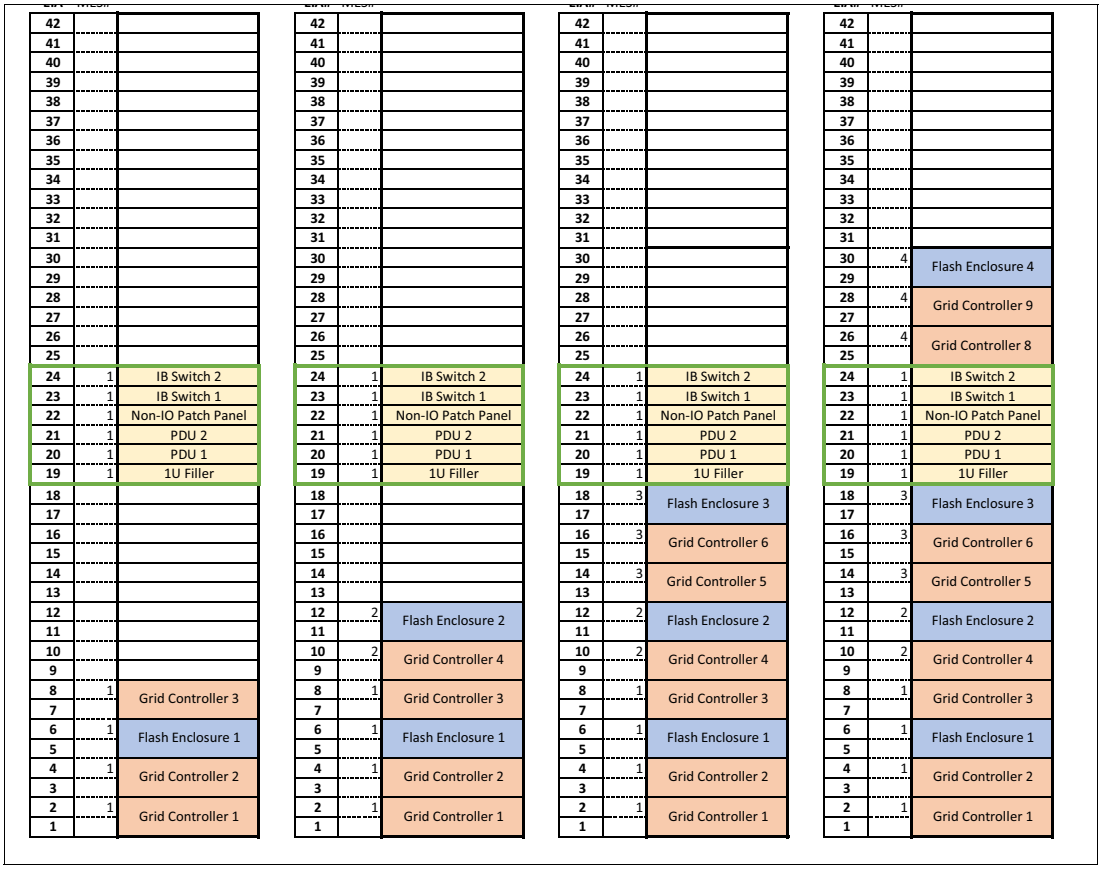

Figure 10 Scaling options for Model 425

All data that is stored on the system is evenly redistributed across all flash enclosures during the installation process so that all grid modules and flash enclosures are evenly used.

Depending on the number of grid elements in your order, they are stacked in the rack in the sequence that is shown. The next grid element will always be installed in the next free location in the rack, starting from the bottom. Grid elements that are installed must all be the same type (interface options and MicroLatency module size). An intermix of interface options or MicroLatency module capacities is not supported.

Product physical specifications (Model 425/U25)

Two machine types are associated with FlashSystem A9000R Model 425. They are available with the following standard warranty periods, as listed in Table 2. Model U25 is only available with a three-year warranty.

Table 2 Machine types and models and warranty periods

Warranty period	**IBM FlashSystem A9000R**
One-year	9835-425
Three-year	9837-425 or 9837-U25

Table 3 lists the components that are included in Model 425, and available capacity options.

Table 3 FlashSystem A9000R Model 425 configurations

FlashSystem A9000R Model 425 configurations			
Grid elements	2	3	4
Grid controllers	4	6	8
CPUs (cores)	8 (96)	12 (144)	18 (216)
Memory in GB	1536	2304	3072
iSCSI only ports	16	24	32
iSCSI + FC ports	8 + 16	12 + 24	16 + 32
Flash enclosures	2	3	4
MicroLatency modules	24	36	48
MicroLatency module in TB	3.6/8.5/18	3.6/8.5/18	3.6/8.5/18
Usable physical capacity TB	72/170/360	108/255/540	144/340/720
Effective capacity in TB[a]	360/850/1800	540/1275/2700	720/1700/3600
Maximum effective capacity in TB[b]	2400/2400/2400	3600/3600/3600	4800/4800/4800

a. Effective capacity assumes a data reduction calculated at about 5:1.
b. Maximum effective capacity is the up-most provisioning limit that effective capacity can be stretched to.

Rack dimensions

FlashSystem A9000R rack dimension and clearance requirements are listed in Table 4.

Table 4 Rack dimensions and clearance

Dimension and clearance	Measurement
Height	201.5 cm (79.3 in.)
Depth	129.7 cm (51.1 in.)
Width	64.4 cm (25.4 in.)
Front clearance	120 cm (47.2 in.)
Rear clearance	100 cm (39.4 in.)
Door clearance	10 cm (3.9 in.)

The optional rear door heat exchanger (feature code AFR1) is an available water-cooled device that can be mounted on the rear of an FlashSystem A9000R system.

Delivery clearance requirements

The clearance measurements that are required for delivery through all doors and elevators are listed in Table 5. These measurements are for the typical height of the pallet. The measurements do not include more clearance than is needed to raise the pallet on a pallet jack for movement.

Table 5 Typical delivery clearance requirements

Dimension	Clearance requirement
Height	216 cm (85.0 in.)
Depth	144 cm (56.7 in.)
Width	94 cm (37.0 in.)

Delivery weight requirements

The path from the truck and to the server room must support the weight of a fully configured rack, including packaging materials, which is 809 kg (1783 lbs.). For racks with fewer than four grid elements, subtract 80 kg (176 lbs.) for each grid element less than four to determine the approximate weight requirement for your rack. The entry configuration with two grid elements weighs 649 kg (1,430 lbs.).

Floor-load requirements

You must ensure that the floor load rating can support the weight of the FlashSystem A9000R, as shown in Table 6.

Table 6 Floor weight-support requirements

Grid element configuration	Floor reinforcement area	Total weight
2 grid elements	66 cm x 118 cm (26 in x 46.5 in)	616 kg (1358 lbs)
3 grid elements	66 cm x 118 cm (26 in x 46.5 in)	695 kg (1532 lbs)
4 grid elements	66 cm x 118 cm (26 in x 46.5 in)	774 kg (1706 lbs)

Height and weight reduction features

FlashSystem A9000R arrives fully assembled with all components in place, unless the height and weight reduction shipping options are ordered.

If the site does not meet the delivery clearances or more clearance is needed to move the FlashSystem A9000R rack through low-clearance obstacles, the height reduction shipping feature (feature code AFR2) must be ordered. The height reduced option reduces the height by 30 cm (11.8 in).

The weight-reduction feature (feature code AFR3) removes components from the rack and ships them separately. This option leaves the rack weighing approximately 423 kg (932 lbs.) and allows the rack to be tilted as much as necessary to fit under low doorways.

Power requirements

FlashSystem A9000R system features redundant main-power cables. A power supply must be provided from two independent electricity sources.

The following AC power source configurations are available:

- Two or four (dependent on configuration's scale-out power load) 60/63 A, 200 - 240 V AC, North American, EMEA, and Japan single-phase receptacles, each connected to a different power source.
- Two 60 A, 200 - 240 V AC, US and Japan delta three-phase receptacles, each connected to a different power source.
- Two 30/32 A, 200 - 240 V AC (Line-to-Neutral [LN]), EMEA WYE three-phase receptacles, each connected to a different power source.

Power consumption

Before starting the physical installation, ensure that an electrician is available who can fulfill the requirements for connecting FlashSystem A9000R.

Table 7 lists the typical and maximum power usage.

Table 7 Power usage in KW

Configuration	Typical	Maximum
2 grid elements (Minimum)	3.085 kW	4.516 kW
4 grid elements (Full)	5.996 kW	8.671 kW

Table 8 lists the maximum power consumption of A9000R Model 425 configurations.

Table 8 Max power consumption in kVA

Configuration	3.6 TB MicroLatency modules[a] Idle / light load power consumption in kVA	8.5 TB MicroLatency modules[b] Idle / light load power consumption in kVA	18 TB MicroLatency modules Idle / light load power consumption in kVA
2 grid elements	3.258	3.338	3.418
3 grid elements	4.791	4.911	5.031
4 grid elements	6.324	6.484	6.644

a. The numbers for power consumption of 3.6 TB MicroLatency modules are calculated estimates.
b. The numbers for power consumption of 8.5 TB MicroLatency modules are calculated estimates.

Thermal dissipation

Table 9 lists the cooling (thermal dissipation) for the different configurations of FlashSystem A9000R Model 425. To support capacity upgrades, the installation site must provide cooling capacity to support full-rack configurations.

Table 9 Thermal dissipation in kBTU/hour

FlashSystem A9000R Model 425	kBTU/hour
2 grid elements	10.5
3 grid elements	15.8
4 grid elements	21.0

Scale out with IBM Hyper-Scale Mobility

Scaling from a FlashSystem A9000R to a FlashSystem A9000 or A9000R is possible by using the IBM Hyper-Scale Mobility function.

Hyper-Scale Mobility can move volumes from any FlashSystem A9000R to another FlashSystem A9000 or A9000R, allowing you to distribute application I/Os to more systems and move data from one system to another. Upon completion of the volume move, the host is transparently and automatically redirected to the new system.

Hyper-Scale Mobility addresses the following scenarios:

- Scaling between FlashSystem A9000 and A9000R systems
- Balancing workloads across systems without service downtime for better performance
- Retiring systems gracefully and upgrading to current technology
- Detaching storage and host maintenance cycles
- Managing storage growth

Starting with FlashSystem A9000R Software V12.2.1, Hyper-Scale Mobility is also supported from an XIV Gen3 with code level 11.6.2a to FlashSystem A9000R or A9000.

Reliability, availability, and serviceability

The unique modular design and logical topology of FlashSystem A9000R fundamentally differentiates it from traditional, monolithic systems. This architectural divergence extends to the exceptional reliability, availability, and serviceability (RAS) aspects of the system.

FlashSystem A9000R also incorporates autonomic and proactive monitoring and self-healing features. These features enable preventive measures to preserve data redundancy before a component malfunction occurs.

The system is automatically restored to full redundancy within minutes of a hardware failure. When a grid controller fails, its workload is directly taken over by another grid controller.

For more information about the reliability features of a flash enclosure, see “IBM FlashCore and 2D RAID technology” on page 20.

Reliability

Reliability is engineered at the following levels:

- The separation of grid controllers and flash enclosure protects against the effects of a failed grid controller. A grid controller can fail without any effect to the flash enclosure. The tasks of a failed grid controller are taken over by the other grid controllers. Correct host multipathing must be used to prevent host disconnection.
- Redundant hot-swappable components:
  - Each flash enclosure includes two clustered, hot-swappable canisters that each contain two hot-swappable fan modules, two management controllers, four management Ethernet ports, and a USB port for service connectivity. The batteries, fans, and power supplies are all redundant and hot-swappable.
  - If a MicroLatency module failure occurs, critical customer applications can remain online while the defective module is replaced. Each flash enclosure is configured with a hot spare module for use during a MicroLatency module failure.

- Each grid controller contains two redundant, hot swappable power supplies. The cooling system is designed resilient to keep the grid controller running even with up to two fans in failed state. The microcode is stored on two RAID1 secured HDDs. The data and functions of each grid controller is mirrored in a three-way manner, such that up to two grid controller failures can be sustained at the same time.

- The two-dimensional RAID protection (2D-RAID) of the flash enclosure protects against MicroLatency module, flash chip, and other flash system-related failures. 2D-RAID consists of IBM Variable Stripe RAID™ and flash enclosure-wide RAID 5. IBM Variable Stripe RAID is a patented IBM technology that provides an intra-module RAID stripe within each flash module and is described in “Flash enclosure 2D RAID” on page 21. Variable Stripe RAID technology helps reduce downtime and maintain performance and capacity during partial or full flash chip failures.

  A MicroLatency module can fail without any effect to the flash enclosure. When a MicroLatency module fails, the RAID 5 configuration over the MicroLatency Modules allows a rebuild by using the spare MicroLatency Module in the flash enclosure.

- The flash enclosure runs an internal scrubbing process to verify the integrity of the data. It is a low-priority process to optimize performance. If an error is detected during the scrubbing process, the flash enclosure attempts to correct it. If the attempt is unsuccessful (unrecoverable error), an event is sent but the flash enclosure remains online.

- InfiniBand cabling is redundant and split onto two different InfiniBand adapters in each grid controller.

- All active components (grid controllers, flash enclosures, and InfiniBand switches) contain a redundant battery backup unit (BBU). During an accidental power loss on both main power sources, a loss in BBU redundancy, or in an overheating situation, FlashSystem A9000R automatically performs a shutdown to protect the data (cache and metadata). This process is known as *shutdown vaulting*. During normal system operation, the cache and metadata are also saved to the vaulting devices at regular intervals, approximately every 5 minutes (live vaulting). Shutdown vaulting does not overwrite live vaulting.

  Vaulting: The role of the vaulting procedure is to write memory-resident data (which is volatile) onto non-volatile storage during system shutdown.

  FlashSystem A9000R uses the SSDs in the grid controller as vault devices. The vaulting process design point is to save three copies of the data, preferably on SSDs in three different grid controllers. During a hardware failure, the system still saves at least two copies of the data. That is, the system does not remain online with less than two grid controllers.

  The grid controller destages the following data during the shutdown:

  - Data in write cache
  - Metadata, which changed since the last vault run

  The flash enclosure also has redundant BBUs to allow a graceful shutdown of the enclosure. During shutdown, it writes the following data:

  - Data in the flash enclosure write cache
  - Recent data distribution table

  After all of the data is secured, the components power off. If the utility power recovers, after the automatic shutdown, FlashSystem A9000R should start automatically.

When the system restarts, it starts a *devaulting* procedure. The devaulting procedure is retrieving the data from the vault devices back to memory upon system start as part of the system power-up process. Each vaulting device (SSD) reports to the system the piece of data it holds. The system uses an internal vault distribution table to assign each piece of data to cache nodes.

If vaulting or devaulting fails during shutdown or startup (often because a catastrophic hardware or software failure), the system moves to maintenance until IBM intervention.

Availability

Grid controllers feature automatic and seamless failover capabilities. The cache of a grid controller is triplicated. That is, one copy is local and two other copies are on two other grid controllers. The system remains operational if it can still maintain at least one secondary cache. This behavior implies that FlashSystem A9000R, which has a minimum of four grid controllers, can stand two simultaneous grid controller failures. The loss of one other grid controller (an unlikely event) triggers a graceful system shutdown.

System-wide performance monitoring assures the availability of the needed software functions. For example, if a software process (such as caching or data reduction) is unresponsive, they are expelled from the degraded grid controller and their workload is taken over by other grid controllers.

FlashSystem A9000R includes an enhanced call home functionality. When configured for call home, each system reports events regularly and sends heartbeats with system health information to IBM. Based on the events and heartbeats, IBM Support can automatically open support tickets and start service actions, without the need for any manual customer action.

Statistical data, which is gathered by IBM based on the events and heartbeat information, helps IBM identify possible upcoming situations that might need proactive assistance.

Power is monitored, and the battery units are conditioned for longer lifespan.

The system temperature is monitored at the flash enclosure level and at the system level. When the temperature gets out of range, a graceful shutdown is triggered.

Concurrent code load enables customer applications to remain online during firmware upgrades to all components, including the flash enclosures and MicroLatency modules.

When grid elements are added to FlashSystem A9000R, the data that is stored on the flash enclosures is redistributed over all Flash enclosures to ensure a balanced data distribution. The same condition applies for the data that is in the grid controller memory cache. The capacity expansion can be rolled out concurrently without any FlashSystem A9000R downtime.

Serviceability

High levels of serviceability are achieved by providing the following features and functions:

- Thorough testing of all components during the manufacturing process.
- Enhanced Call-home.
- Logs and statistics are collected and recorded by each interface and port that relate to the data path (Fibre Channel, iSCSI, InfiniBand, and Ethernet).
- Debug utilities, including XRAY data collection on FlashSystem A9000R and Host Attachment Kit (HAK) diagnostic collection on the host side.

- IBM SSR has access to service tools for guided repairs, pre-upgrade checks, concurrent upgrade, and so on.
- Remote support capabilities minimizing time to resolution.

IBM FlashCore and 2D RAID technology

The IBM FlashCore technology that is used in FlashSystem A9000R is based on patented mechanisms to deliver extreme performance, MicroLatency, macro efficiency, enterprise-grade reliability, and various operational and cost efficiencies.

The data path inside the flash enclosure is hardware-accelerated, which means that there is no CPU in the data path. This configuration ensures the lowest latency and highest throughput.

IBM FlashCore technology features

Figure 11 shows the following major areas within IBM FlashCore technology and the unique IBM attributes of each technology.

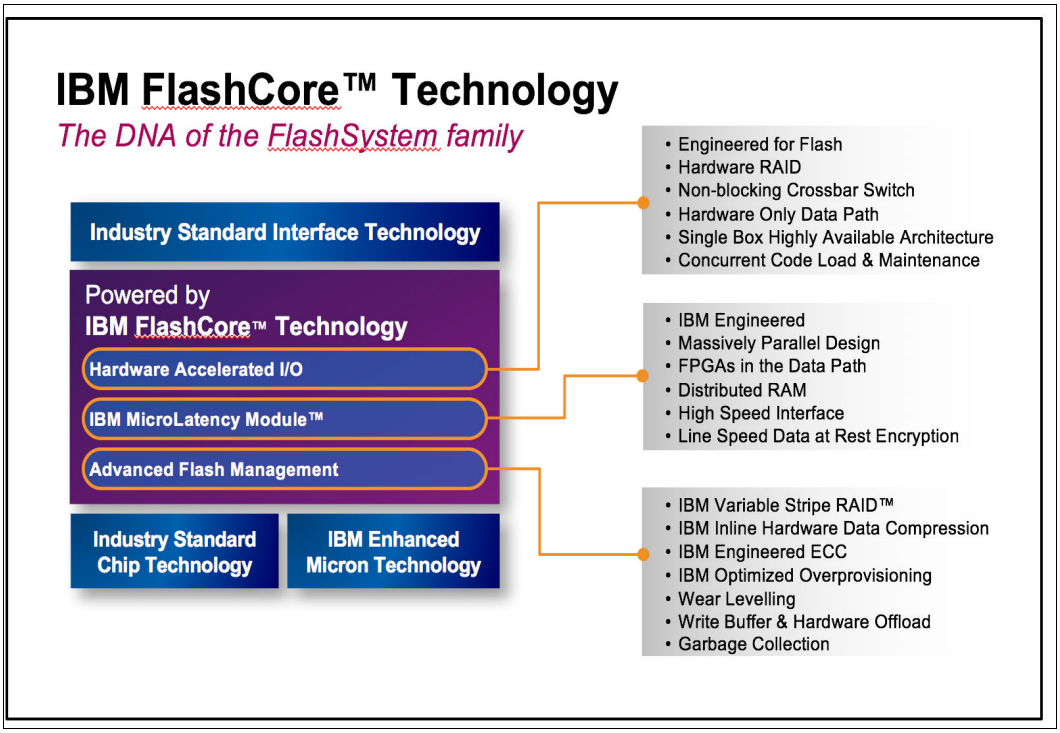

Figure 11 IBM FlashCore technology

- Hardware Accelerated I/O

  The FlashSystem A9000R Flash enclosure hardware design offers several unique IBM components. These components include Hardware RAID, Non-Blocking Crossbar Switch, Hardware-Only Data Path, Highly Available Architecture, Concurrent Code Load, and Concurrent Maintenance.

  The use of an all-hardware data path design assures highest performance and lowest latency of FlashSystem A9000R Flash enclosures.

- IBM MicroLatency modules

  FlashSystem A9000R Model 415 flash enclosures use 20 nm IBM enhanced multi-level cell (MLC) flash card memory chips.

  The FlashSystem A9000R Model 425 flash enclosures use the new IBM enhanced 3D triple-level cell (3D-TLC) flash card memory chips.

  FlashSystem A9000R design also uses IBM Engineered Massively Parallel Design, Field Programmable Gate Array (FPGA) modules in the Data Path, Distributed RAM, and High-Speed Interfaces plus hardware-based data-at-rest encryption.

- Advanced Flash Management

  FlashSystem A9000R has unique patented designs to ensure maximum availability. These designs include IBM Variable Stripe RAID, IBM Inline Hardware Data Compression, IBM Engineered Error Correction Code (ECC), IBM Optimized Over-Provisioning, advanced wear leveling on IBM MicroLatency modules, Write Buffer and Hardware Offload, and IBM Garbage Collection.

  The wear leveling algorithm assures the even usage of all blocks. The garbage collection process collects the blocks (which are no longer used) so that they can be reused for writing.

  Given that FlashSystem A9000R uses software data reduction, the data being sent to the flash enclosure is already compressed and therefore is bypassing the inline hardware data compression.

Flash enclosure 2D RAID

A flash enclosure contains 12 MicroLatency modules. A RAID 5 is built over these modules to protect the flash enclosure from a MicroLatency module failure.

The flash chips inside the MicroLatency module are protected by the IBM Variable Stripe RAID (VSR). Variable Stripe-RAID protects the MicroLatency module against chip failures or if only a part of chip fails. Variable Stripe-RAID monitors the health of the flash media, efficiently detects and manages flash failures, and optimizes the use of all flash resources.

With Variable Stripe-RAID, a flash failure does not result in the need for a maintenance event. No flash module replacement is necessary, and the MicroLatency module is not degraded in any way.

Increased protection: Variable Stripe-RAID protects against expected and unexpected failures inside a flash chip.

The combination of the RAID 5 over the MicroLatency module and the VSR inside a MicroLatency module is called two-dimensional RAID protection (2D RAID).

Figure 12 shows the IBM FlashSystem 2D RAID technology.

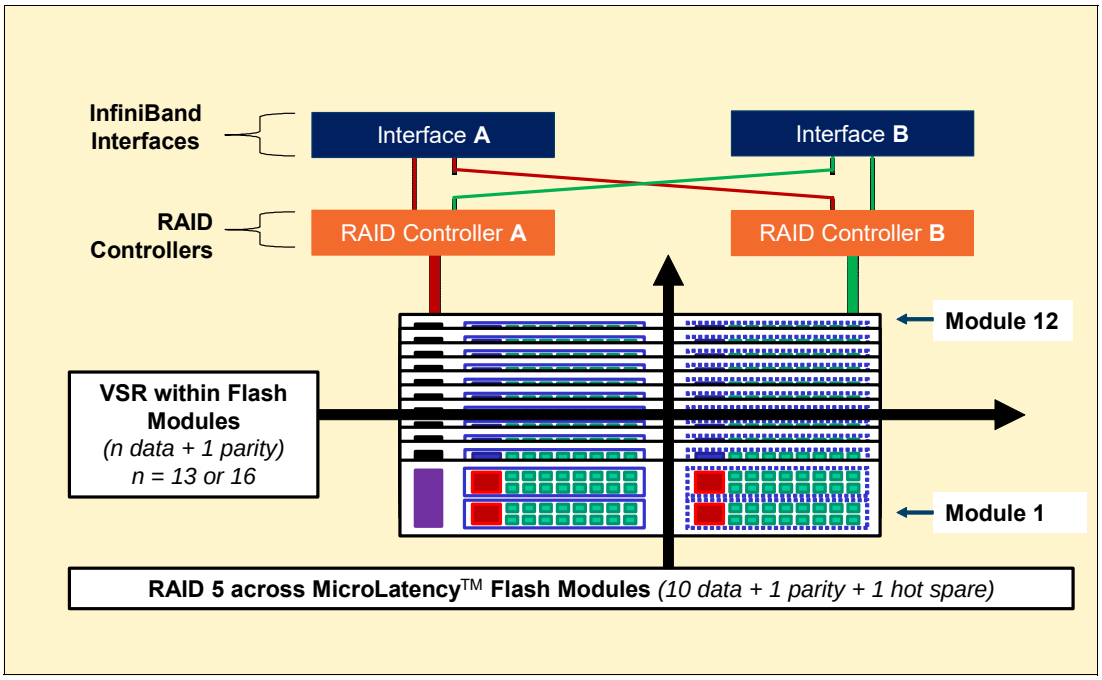

Figure 12 IBM FlashSystem 2D RAID Protection

Logical architecture and functions

FlashSystem A9000R logical architecture is built on the IBM Spectrum Accelerate™ software. The architecture features many added enhancements to optimize the software stack for use with flash storage.

Parallelism and grid architecture

The grid architecture plays an important role in ensuring that all components of FlashSystem A9000R have an active role in servicing host requests. Each grid controller performs the following important roles, which are implemented by specific software functions and designated as nodes:

- Interface: The interface node processes host I/Os. From the physical standpoint, every grid controller has FC or iSCSI cards that can be connected to a network for attachment to application hosts.
- Data reduction: The data reduction node implements data deduplication and compression functions. Each grid controller dedicates some processing capacity and memory for the purposes of data reduction.
- Data distribution: The data distribution process ensures that the distribution information is kept up-to-date, which allows for data placement across all flash enclosures by using 16 MB partitions.
- Caching: The cache node implements and manages caching functions. Data reduction is accomplished below cache in FlashSystem A9000R, so each grid module has significant read and write cache to allow for consistent microsecond response times.

As shown in Figure 13, the various nodes are instantiated and run in parallel on each grid controller. This design enables multiple main threads for higher performance and scalability by adding grid controllers in FlashSystem A9000R. Resiliency and system availability is also improved because any failed node on a controller automatically fails over and can be redistributed to another similar node on a different grid controller.

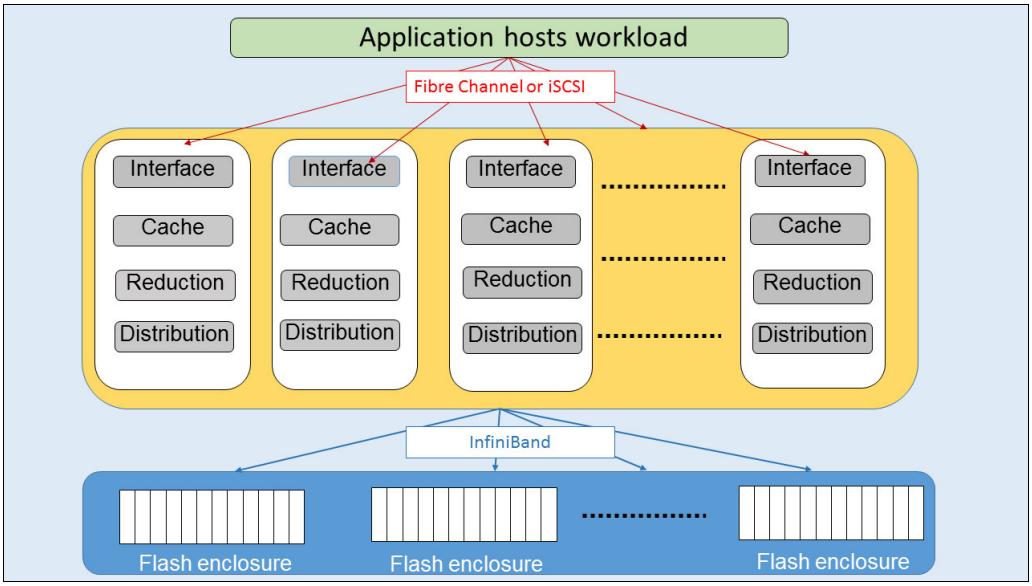

Figure 13 Parallelism and grid architecture

Cache resiliency

The cache and cache management design enables decoupling between computation functions (typically, caching and metadata management) and storage resources.

To ensure resiliency, the system is creating multiple copies of the data in cache. Each host data block has a primary cache in a grid controller that is assigned as the primary module and two other backup caches in two different grid controllers, as shown in Figure 14 (data reduction nodes are not shown).

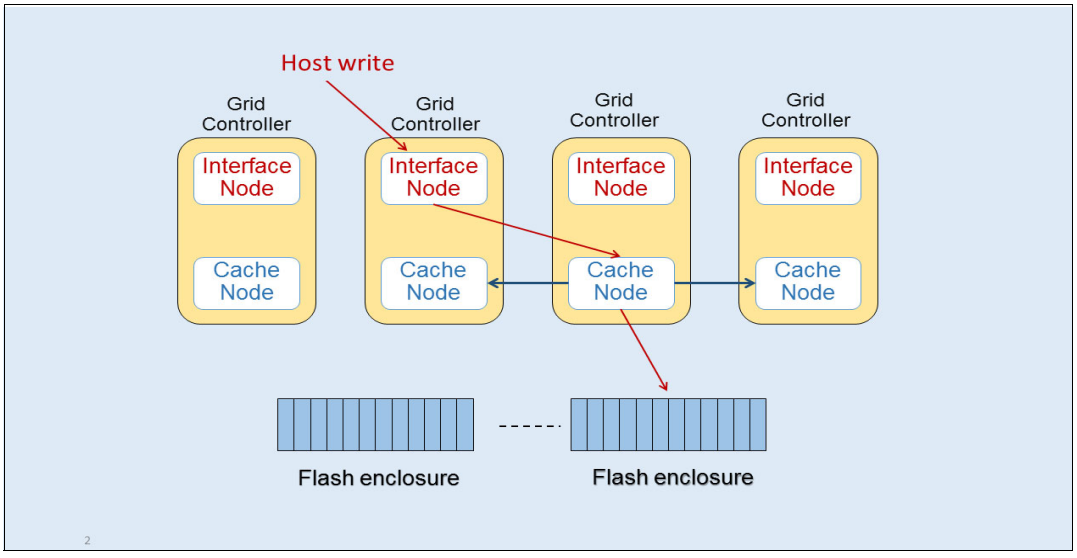

Figure 14 Cache resiliency design

When information is written to FlashSystem A9000R, the primary module ensures that data is also written to both backup modules. The write is acknowledged to the host only when all three copies are in place.

In-line data reduction

FlashSystem A9000R performs always-on, inline global data reduction to provide application hosts with capability to provision virtual storage capacity that is an order of magnitude higher than actual physical capacity. It also delivers microsecond performance benefits of FlashSystem storage at a lower cost per gigabyte.

Data reduction in FlashSystem A9000R uses the following three-phase process:

1. Pattern matching and removal
2. Data deduplication
3. Compression

Below cache: Placement below cache means that there is no latency affect for cached I/Os. System functions, such as migration, snapshots, or even VMware VAAI operations, are not affected.

Pattern matching and removal

This first layer of data reduction comes from pattern matching. Pattern matching mechanisms match incoming host writes with a pre-configured set of known patterns stored in the system.

When a write is processed, it is split into 8 KB blocks, as shown in Figure 15. Each block is then hashed and the hash value is compared to a table of well-known hashes. If a match is found, the corresponding pattern ID, which is only 2 bytes (highlighted by the green arrows in the Removal section of Figure 15) is stored. Any match that is found at that stage is replaced with internal markings (a hash) without performing data deduplication and compression yet.

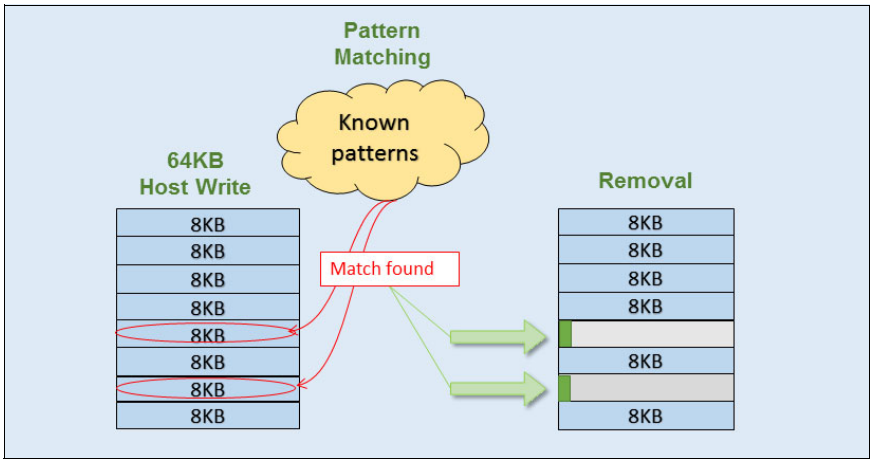

Figure 15 Pattern matching and removal

Data deduplication

Data deduplication is the ability to store data only once, although it can be written many times by various hosts or applications.

The data deduplication mechanism identifies identical blocks of data and stores only one copy of that data in the system. All other identical blocks are pointed to that copy.

In Figure 16, each color represents unique data. Every square represents an 8 KB block. The system can detect duplicates and store only one copy of the duplicate 8 KB blocks. For duplicates, Figure 16 shows that only the pointers to the data are stored in the system.

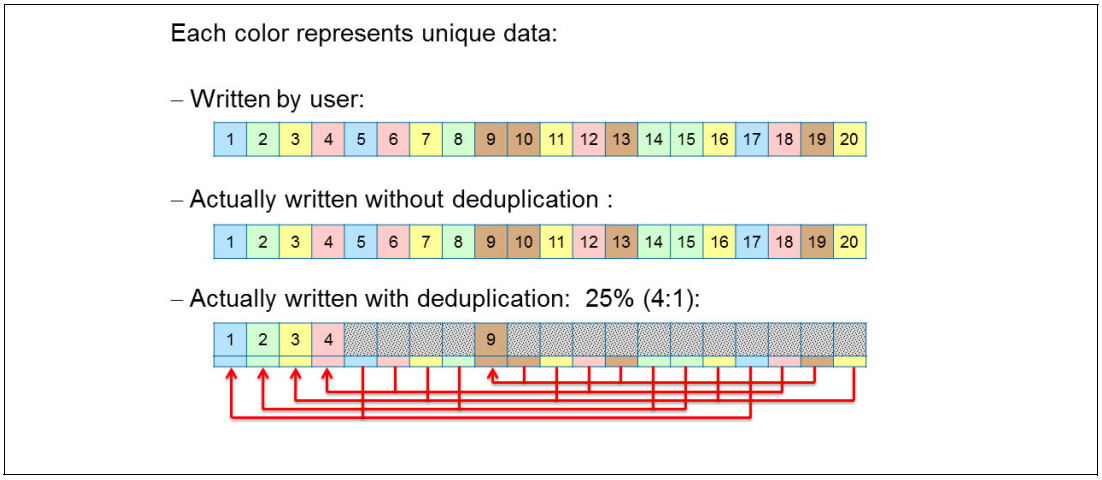

Figure 16 Data deduplication in FlashSystem A9000R

Whenever a new unique block is found, a new hash is created and stored in a repository. The hash value of any subsequent 8 KB writes is checked against the repository for a match.

Data deduplication is done in sequences and the system stores hashes in a memory construct, which is known as a *segment*. Each hash (data) has an owning segment, and a specific segment can also contain references to a hash that it owns or references to a hash in another owning segment. As shown in Figure 17, the owning segment of a referenced hash is indicated by the corresponding background color.

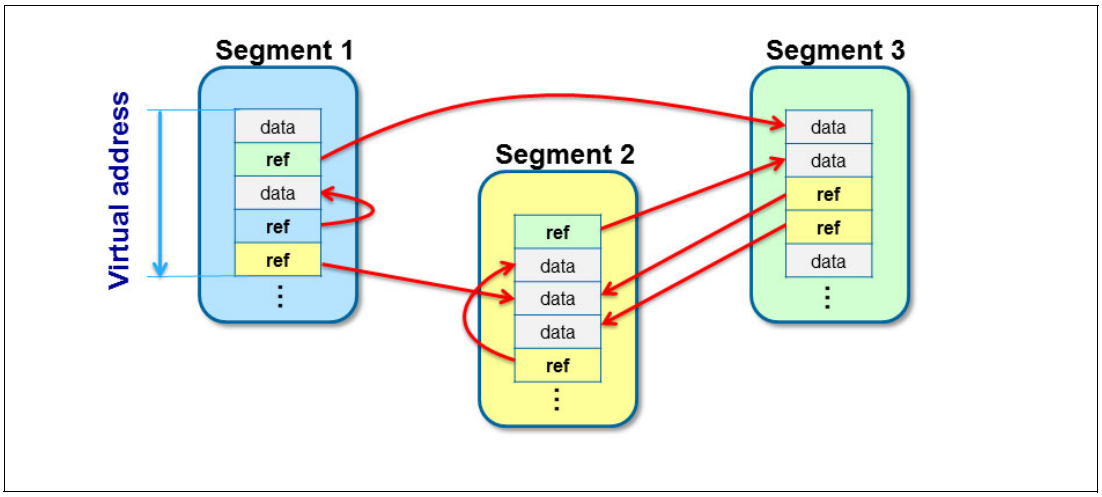

Figure 17 Hashes and references in segments

Segments maintain a list of other segments that they created references to recently. Therefore, when looking for a match, the recent segments are checked first, which typically speeds up the matching process.

As shown in Figure 18, data deduplication of the 8 KB blocks is done over a 4 KB alignment. This process increases the probability of finding a match and results in higher data deduplication percentage.

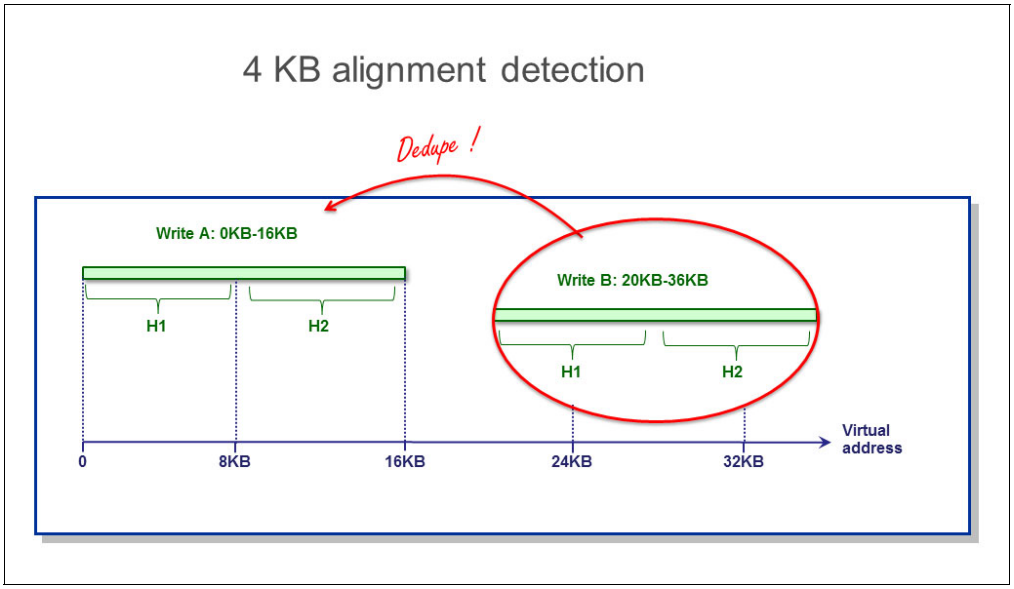

Figure 18 Dedupe: 4 KB alignment detection

Compression

Finally, data moves on to the compression step (see Figure 19) for more data reduction.

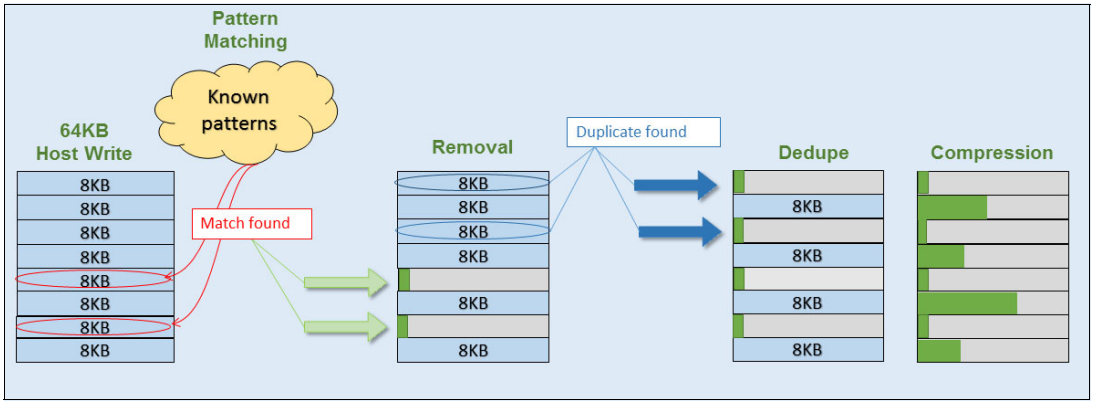

Figure 19 Compression

Compression in FlashSystem A9000R is hardware-assisted. Two Intel Coleto cards are included in each grid controller.

The IBM patented compression technology that is used by FlashSystem A9000R is based on a `zlib` data compression algorithm that operates in a real-time method.

The compression engine alters the traditional approach to compression. It uses variable-size chunks for the input and fixed-size, 32 KB chunks for the output. This difference is the basis of many of its benefits.

Fixed size writes: Traditional compression writes variable size chunks to the storage device, whereas FlashSystem A9000R compression writes fixed size output chunks.

In addition, FlashSystem A9000R uses *temporal locality*-based compression. As shown in Figure 20, temporal compression adds the time dimension that is not available to other compression algorithms. It offers a higher compression ratio because the compressed data in a block represents a more homogeneous input data.

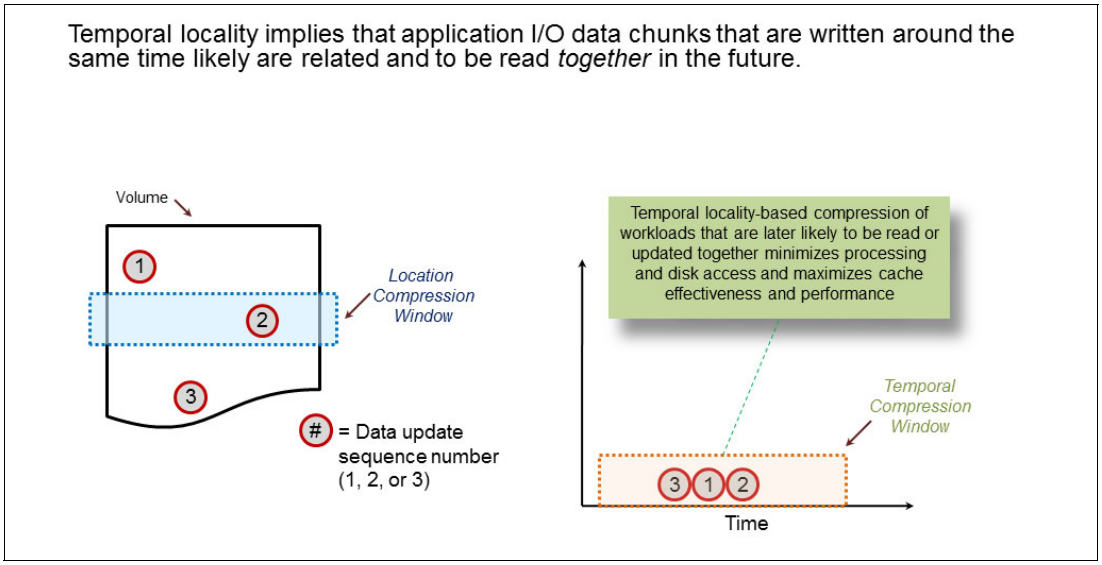

Figure 20 Temporal locality

Storage provisioning concepts

This section describes how the available physical storage is virtualized and effectively managed in FlashSystem A9000R.

Storage Pools

The available capacity in the system can be administratively portioned into separate and independent storage pools.

A pool must have an allocated size that is greater or equal to the total size of volumes and snapshots that it will contain. The minimum size of a pool is 103 GB.

Tip: With Version 12.3, a pool can be system-wide. In other words, a single pool can use the full system effective capacity, up to the system allocation limit.

Volumes

A *volume* is defined within the context of only one storage pool. Because storage pools are logical constructs, a volume and any snapshots that are associated with it can be moved to any other storage pool. As a benefit of the system virtualization, there are no limitations on the associations between logical volumes and storage pools.

FlashSystem A9000R uses the grid concept and distributes volume data evenly across hardware resources. The data is distributed evenly across all Flash enclosures by using partitions, and each partition is 16 MB.

The minimum volume size that can be created in FlashSystem A9000R is 1 GB, and the maximum size is 1 PB.

Snapshots

A snapshot is a point-in-time copy of a volume's data and is contained within the same storage pool as the source. As implemented in FlashSystem A9000R, snapshots have minimal effect on system performance. When the original data is updated, the update is stored in a new partition and a pointer of the original volume now points to the new partition. However, the snapshot volume still points to the original partition. This method is called *redirect-on-write*.

Consistency groups

A *consistency group* is a group of volumes of which a snapshot can be made at the same point, which ensures a consistent image of all volumes within the group at that time. This consistency between the volumes in the group is paramount to maintaining data integrity from the application perspective. By first grouping the application volumes into a consistency group, it is possible to later capture a consistent state of all volumes within that group at a specified point by using a special snapshot command for consistency groups.

Multi-tenancy and QoS

Multi-tenancy brings flexibility and simplicity to managing tenant data and storage resources across multiple FlashSystem A9000R systems by using the following methods:

- Secure division and isolation of FlashSystem A9000R storage pools, volumes, consistency groups, mirrors, data migrations, and quality of service performance classes among numerous tenants
- Simple, quick delegation of administration tasks and role-based permissions
- Simple, rapid deployment without the need for extensive planning and tuning, and the ability to scale out a FlashSystem A9000R at the customer site

Domains

Multi-tenancy is based on the concept of *domains*, in which FlashSystem A9000R is logically partitioned into one or more independent containers, each with its own assigned administrators. This configuration enables secure isolation from other domains of the logical entities that are contained within a domain.

A user who is associated with a single domain has no knowledge of the other domains that are on the system nor about the pools or volumes that are associated with those domains. Domains can be associated with the following entities:

- Users and user groups
- Storage pools (and inherently, the volumes that they contain)
- Hosts and clusters
- Remote mirror targets

Note: Although a storage pool (and the volumes that it contains) can be associated with only a *single* domain, users (and user groups), hosts (and host clusters), and remote mirror targets can be associated with *multiple* domains.

A domain restricts the resources that a user can manage. A user can manage only the parts of the system that are associated with the domains with which they are associated, as shown in Figure 21.

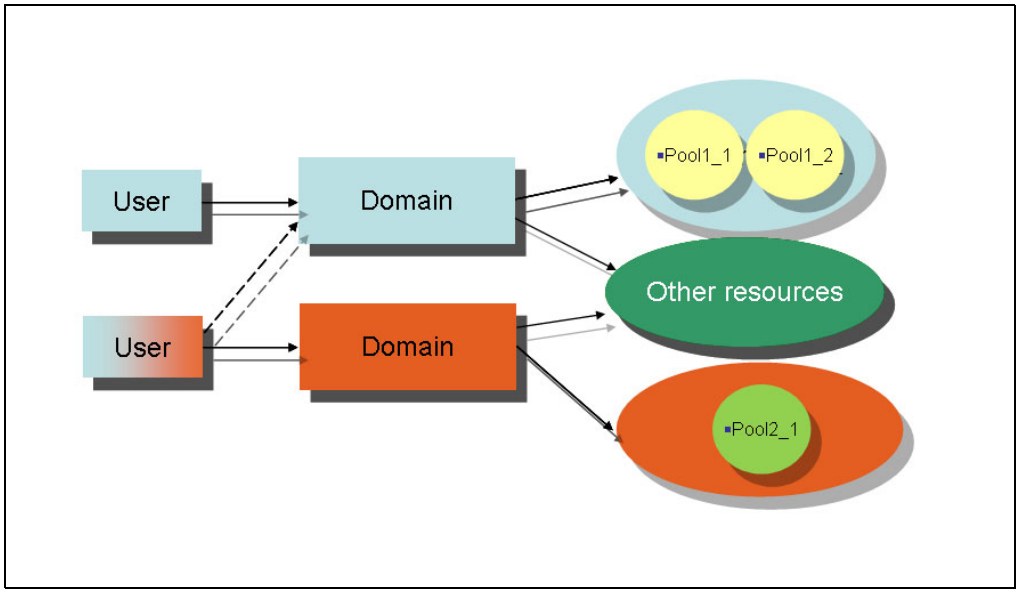

Figure 21 User view of domains and resources

Quality of service

The QoS feature allows FlashSystem A9000R to deliver different service levels to hosts that are connected to the same system.

The QoS feature favors performance of critical business applications that run concurrently with noncritical applications. Because FlashSystem A9000R resources are shared among all applications and all hosts are attached to the same resources, division of these resources among both critical and noncritical applications might have an unintended adverse performance effect on critical applications.

QoS can address this issue by limiting the rate (based on bandwidth and IOPS) for non-critical applications. Limiting performance resources for non-critical applications means that the remaining resources are available without limitation for the business-critical applications.

The QoS feature is managed through the definition of performance classes and then associating hosts with a performance class. This feature can also be set by domains, storage pools, and volumes. Each performance class is implicitly 1 of 2 types: Host or pool/volume/domain.

Consider the following points about the QoS feature:

- Up to 500 performance classes are configurable.
- QoS is applicable to host, domain, pool, volume, and restricted combinations of these entities. For instance, hosts cannot be specified for a performance class that contains a domain or pool.

- Limits can be defined as *Total*, meaning for FlashSystem A9000R systems as a whole, or *Per Interface*.
- Limits are specified as IOPS or bandwidth, as shown in Figure 22.

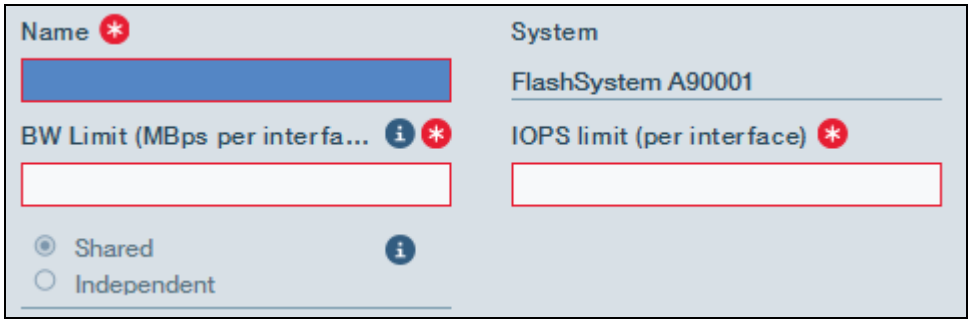

Figure 22 Setting QoS limits

Security

Security is of utmost importance for mission-critical workloads. FlashSystem A9000R has many features to ensure that access and data are secure.

Local security

To prevent unauthorized access to the configuration of the storage system and ultimately to the information that is stored on its volumes, the FlashSystem A9000R systems use password-based user authentication.

By default, FlashSystem A9000R is configured to use native (locally managed) user authentication. Native user authentication uses the credential repository that is stored locally on FlashSystem A9000R. The local credential repository maintains the following information:

- Domain Memberships
- User name
- User password
- User role
- User group
- Optional account attributes

Native authentication mode implements user role mechanism as a form of role-based access control (RBAC). Each predefined user role determines the level of system access and associated functions that a user is allowed to use.

LDAP support

FlashSystem A9000R offers the capability to use LDAP server-based user authentication.

When LDAP authentication is enabled, the system accesses a specified LDAP directory to authenticate users whose credentials are maintained in the LDAP directory.

The benefits of an LDAP-based centralized user management can be substantial when considering the size and complexity of the overall IT environment. Maintaining local user credentials repositories is relatively straightforward and convenient when dealing with only a few users and a few storage systems. However, as the number of users and interconnected systems grows, the complexity of user account management rapidly increases. Managing such an environment becomes a time-consuming task.

Encryption for data-at-rest

FlashSystem A9000R provides optional encryption of data at rest. Encryption can be enabled during the installation of the system, or at any time later. While encryption is not enabled, the system is unlikely to meet customers' or legal compliance standards, and the data is not protected against security issues.

Encryption is hardware-based AES-XTS 256 with centralized key management.

Data-at-rest encryption protects the data that is stored on the grid controller SSDs and flash enclosure MicroLatency modules against unauthorized access, use, disclosure, disruption, modification, perusal, inspection, recording, and destruction. Data-at-rest encryption protects the data if the SSDs or flash enclosure MicroLatency modules are stolen or improperly discarded.

FlashSystem A9000R allows a choice between an external key manager-based implementation and a local key-based encryption implementation.

To provide centralized and simplified key management and the separation of key storage from data storage, FlashSystem A9000R implements an external key management scheme. In this scheme, key management is accomplished by using external Key Management Interoperability Protocol (KMIP) compliant servers, such as IBM Security Key Lifecycle Manager or Gemalto SafeNet KeySecure server.

FlashSystem A9000R cache backup SSDs and flash enclosure MicroLatency modules feature self-encrypting capabilities that provide a local key management option. Local key management enables system support for key management services without requiring a dedicated, independent key management server. By avoiding a dedicated key server, the cost and complexity of managing keys can be reduced, potentially translating into a lower system total cost of ownership. The local key solution offers a simplified deployment of data-at-rest encryption, but clients must ensure that it is adequate for their data security requirements.

Concurrent conversion from external key management to internal key management is supported. However, the reverse operation of changing from local key to an external key server, first erases any data already on disk.

Physical access security

If someone gains physical access to the equipment, that person might manually shut off components by bypassing the preferred process. In this case, the storage system is likely to lose the contents of its volatile caches, which results in a data loss and system unavailability. To eliminate or greatly reduce this risk, FlashSystem A9000R can be equipped with lockable doors.

Storage management user interface

IBM Hyper-Scale Manager introduces a new web-based management graphical user interface (GUI) from which one or more supported FlashSystem A9000R can be managed and monitored in real time from a web browser.

The following functional highlights are included:

- All encompassing customizable dashboard
- Context-oriented user interface in a single-page, web-based application that enables viewing all relevant information for every object at a glance

- Smart view of object relationships and dependencies in a visual map (for example, view all volumes that are mapped to a host)
- Instant object-centered management and monitoring
- Advanced filters for focusing on the required object
- Quick tracing of objects and fast navigation between objects
- One-click selection and operation options (map, unmap, delete, and so on)
- Health score of all systems in the inventory
- Integrated statistics information

The main features are shown in Figure 23.

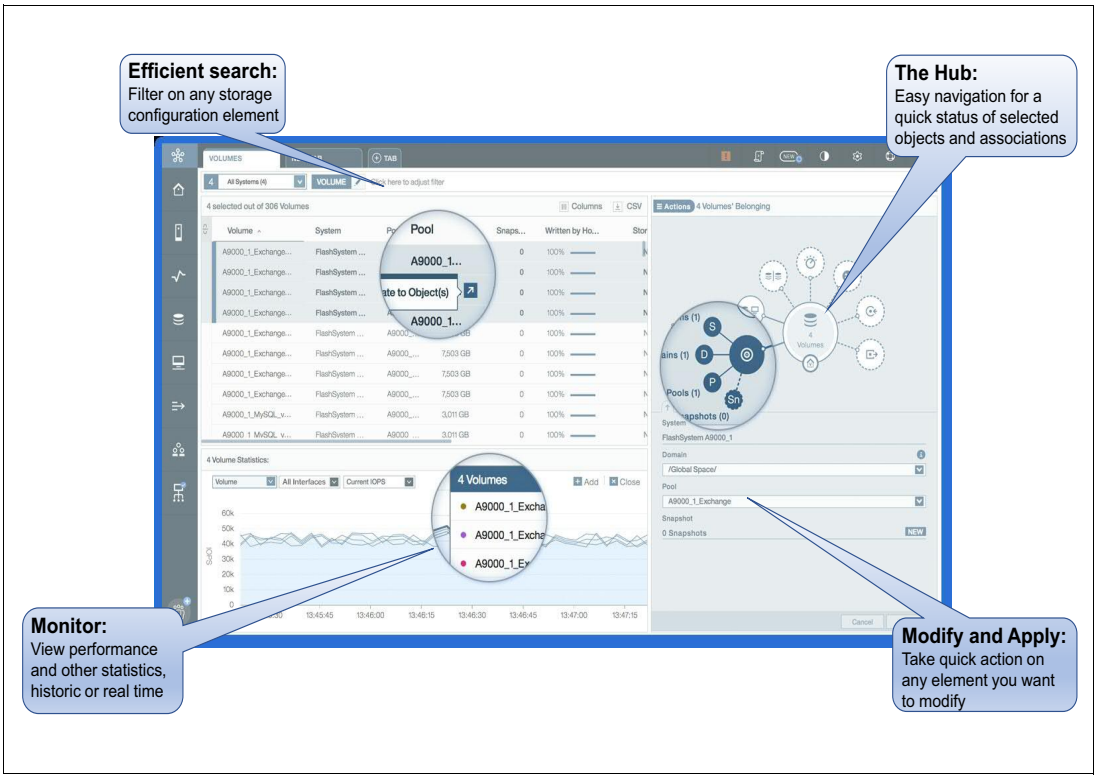

Figure 23 Hyper-Scale Manager GUI

Hyper-Scale Manager Server

The IBM Hyper-Scale Manager is a server application that provides the GUI that is used to manage FlashSystem A9000R. It is installed on a separate host or virtual machine, which runs RedHat Enterprise Linux or CentOS as the operating system. The system requirements are listed in Table 10.

Table 10 Hyper-Scale Manager requirements

Component	Requirements
Environment	Physical host or a virtual machine
Operating System	RedHat Enterprise Linux (RHEL) x64 version 6.x or 7.x, 64-bit CentOS 6.8 or 7.2
CPU	At least two physical cores

Component	Requirements
Memory	Minimum of 4 GB
Disk Space	Minimum of 76 GB in the installation path and 1 GB in `/tmp` directory
Network	One 1 GbE (or faster) Ethernet connection

To access the management web interface and for the Hyper-Scale Manager server to communicate with FlashSystem A9000R, some network ports must be opened. Table 11 lists the ports that must be opened in the OS firewall.

Table 11 Firewall ports for Hyper-Scale Manager

Open ports needed	Direction	Port number
Simple Mail Transfer Protocol (SMTP)	Outbound	25
Backend communication with storage systems	Outbound and inbound	7778
Web User Interface (over HTTP)	Inbound	8080
Web User Interface (over HTTPS)	Inbound	8443
Cloud Integration	Inbound	8440

Related information

For more information, see the following resources:

- *IBM FlashSystem A9000 and IBM FlashSystem A9000R Architecture and Implementation*, SG24-8345.
- *IBM Hyper-Scale Manager for IBM Spectrum Accelerate Family: XIV, FlashSystem A9000 and A9000R, and Spectrum Acceleratey*, SG24-8376
- *IBM HyperSwap and Multi-site HA/DR for IBM FlashSystem A9000 and A9000R*, REDP-5434
- *IBM FlashSystem A9000 and A9000R Business Continuity Solutions*, REDP-5401
- *IBM FlashSystem A9000, IBM FlashSystem A9000R, and IBM XIV Storage System: Host Attachment and Interoperability*, SG24-8368
- *Data-at-rest Encryption for the IBM Spectrum Accelerate Family*, REDP-5402
- IBM FlashSystem A9000R on IBM Knowledge Center:

  `http://www.ibm.com/support/knowledgecenter/STJKN5`

  The following publications are available:

  - *IBM FlashSystem A9000R Command-Line Interface (CLI) Reference Guide*, SC27-8711
  - *IBM FlashSystem A9000R Product Overview,* GC27-8558
  - *Hyper-Scale Manager 5.3 REST API Specification*, SC27-6440
  - *Hyper-Scale Manager 5.3 User Guide*, SC27-8560
  - *IBM FlashSystem A9000R Models 9835-415, 9837-415, 9835-425, 9837-425 and 9837-U25 Deployment Guide,* GC27-8565

- IBM Offering Information page (announcement letters and sales manuals):

  http://www.ibm.com/common/ssi/index.wss?request_locale=en

  At this page, enter A9000R and then, select the information type. Click **Search**. On the next page, narrow your search results by geographical location and language.

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