Definitive Guide to Nutanix AOS Storage

High Performance Software-defined Storage to Meet Modern Infrastructure Needs

NUTANIX

Table of Contents

Meeting the Storage Requirements of Modern IT

In today's digital world, your IT operations need to become more dynamic—and storage is no exception. You need storage services that are flexible, resilient, and simple to manage so your team can focus its attention on higher-value objectives. Unfortunately, legacy SAN storage may no longer meet your needs as it requires constant performance tuning and has limited resiliency, with slow rebuilds and degraded performance. Isolated storage silos may need near-constant attention by hard-to-find storage experts—and still not satisfy your rapidly evolving needs.

While software-defined storage presents a simpler and more flexible approach to address modern storage needs, not all software-defined storage solutions are created equal. Some alternatives may require significant redesigns, thereby complicating deployment, management decisions, and the overall process of choosing the right solution for your specific needs.

Nutanix pioneered the concept of hyperconverged infrastructure (HCI) to address the challenges of legacy three-tier architectures with SAN arrays. Instead of centralized storage, Nutanix AOS Storage provides storage capable of delivering consistent high performance with resilience, flexibility, and a simple management experience. The benefits of AOS Storage include:

- **Resilience.** A self-healing design handles disruptions in real time

- **Distribution.** The storage workload is distributed across all nodes in a cluster using cloud design principles with no single points of failure.

- **Scalability.** Storage capacity and performance grow in lockstep with your needs, minimizing large upfront expenditures and forklift upgrades.

- **Automation.** One-click simplicity and application-aware, policy-based management enable IT generalists to use and manage storage effectively.

- **Performance.** Capable of delivering millions of IOPs with consistent sub-millisecond response times.

What This Guide Covers

AOS Storage simplifies provisioning and data management tasks and elevates IT teams to focus on the applications and services that power business. This book explores the following topics:

- AOS Storage Fundamentals

- Backup and DR

- Resiliency

- Platform Security

- Performance

- Configurations & Manageability

- Data Efficiency

A final section explores how AOS Storage stacks up against traditional SAN in the real world.

AOS Storage: Fundamentals

AOS Storage utilizes a distributed approach that combines the storage resources of all nodes in a Nutanix cluster to deliver the capabilities and performance that you expect from SAN storage while eliminating much of the cost, management overhead, and hassle that comes with managing traditional storage. Intelligent software enables AOS Storage to appear on a hypervisor—such as VMware ESXi or Nutanix AHV—as a single, uniform storage pool. Over the years, Nutanix has expanded its features and capabilities, making AOS Storage a leader in software-defined distributed storage.

Each node in a Nutanix cluster runs a VM called the Controller Virtual Machine (CVM) that runs the distributed storage services as well as other services necessary for a cluster environment. Because storage and other Nutanix services are distributed across the nodes in the cluster, no one entity is a single point of failure. Any node can assume leadership of any service.

To learn more about the underlying components of AOS Storage, refer to the Nutanix Bible.
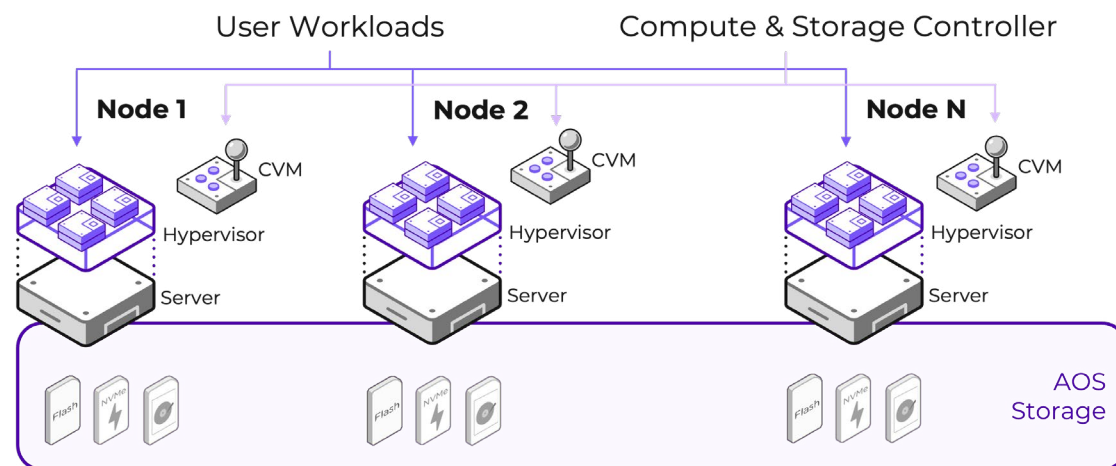
Scalable Metadata

One of the key elements of AOS Storage is a unique approach to metadata. Metadata is divided into global and local metadata stores to optimize metadata locality, limit network traffic for metadata lookups, and improve performance. The global metadata is used to store logical information—like which node data is stored on—while local metadata stores specific information about the physical location of data. This provides flexibility and optimizes updates to metadata.
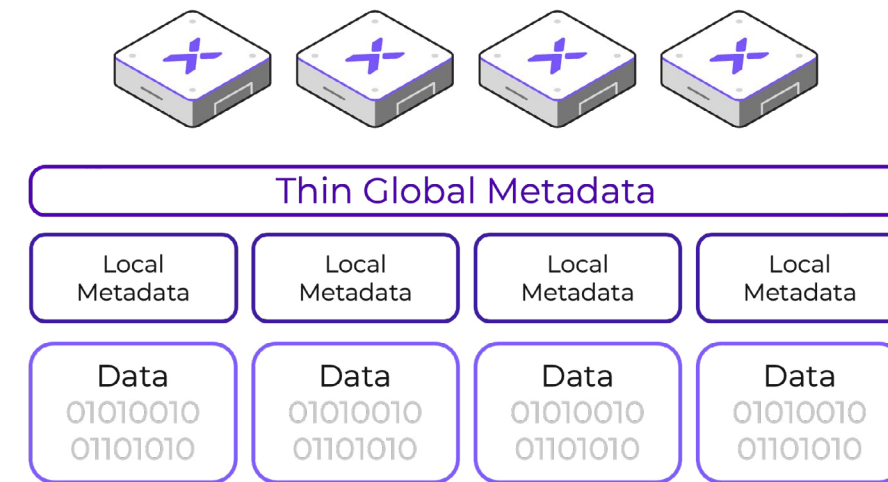
The distributed metadata store allows AOS Storage to split vDisks into fine-grained data pieces for storage delivering dynamic and automated data placement and management, ensuring better, more consistent performance overall. Missing data copies are immediately rebuilt by AOS Storage during failures thanks to fine-grained metadata and distributed placement.

For more information on how AOS Storage manages metadata, refer to the Nutanix Bible.

Key Concepts

AOS Storage is based on several key concepts that can be helpful to know about:

Storage Container. A logical segmentation of capacity from the physical storage pool available across a cluster. Storage containers hold the virtual disks (vDisks) used by virtual machines (VMs). Physical storage is allocated to the storage container as needed when data is written. Storage efficiency features such as compression, replication factor, and QoS are enabled at the container level or on a per VM basis.

vDisk. Virtual disks or vDisks are created within a storage container to provide storage for VMs.

OpLog. A persistent write buffer much like a filesystem journal, the OpLog handles bursts of random writes, coalesces them, and then sequentially moves the data to an Extent Store.

Extent Store. Persistent bulk storage spanning all device tiers that are present in a cluster (NVMe, SSD, HDD).

Unified Cache. A dynamic read cache used for data and metadata that is stored in the CVM's memory. A read request for data not in the cache is read from the Extent Store and placed into the Unified Cache until evicted.

Anatomy of an I/O

The various storage elements described above play essential roles in streamlining I/O and enhancing performance. Incoming sequential writes and sustained random writes bypass the OpLog and enter the Extent Store directly. Bursty random writes enter the OpLog and are coalesced before draining to the Extent Store. Reads are satisfied from the Unified Cache whenever possible. Any read not in the cache is read into the cache from the Extent Store. This approach optimizes performance for both random and sequential writes and ensures that a large percentage of reads are satisfied from the cache for most workloads.
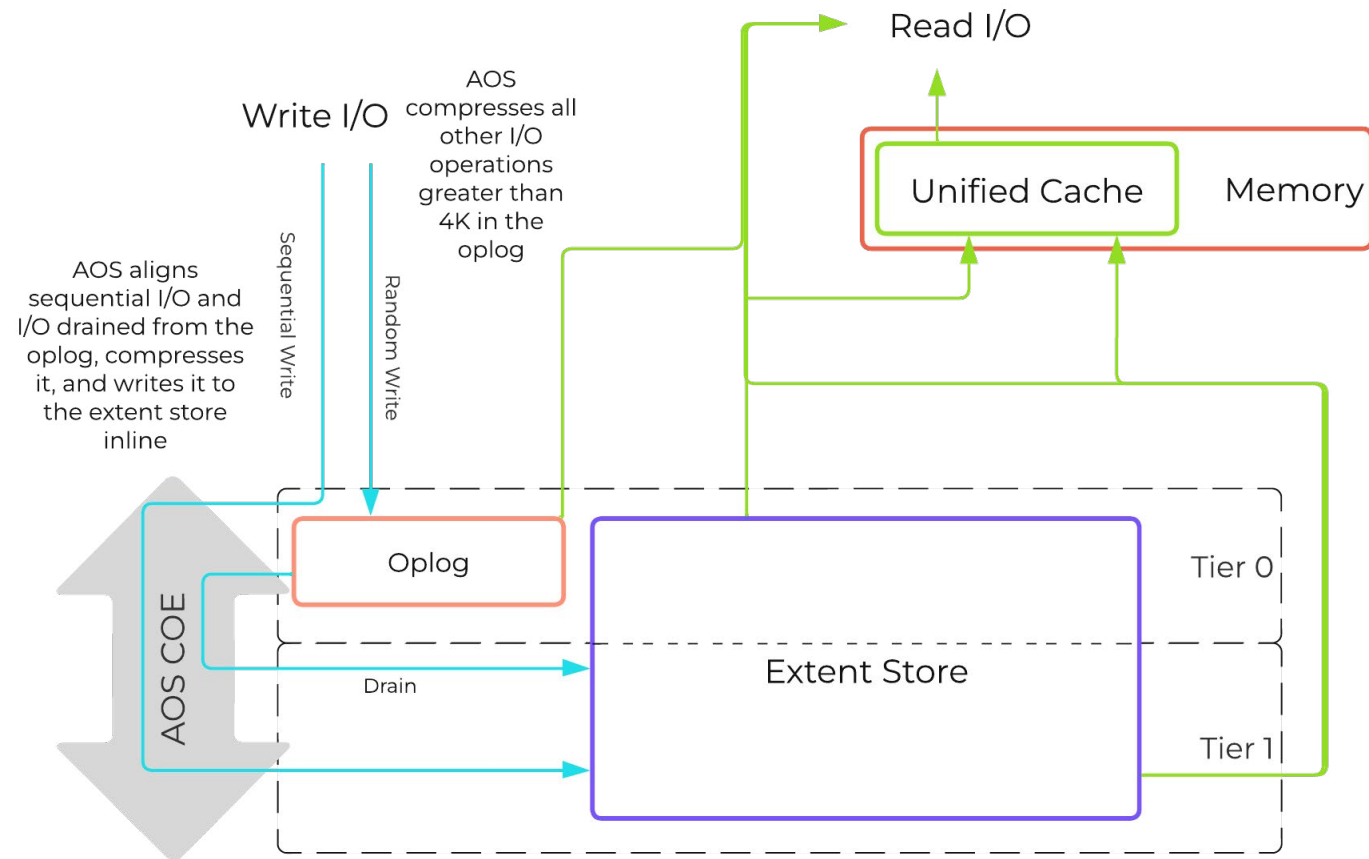
AOS Storage: Resiliency

In the digital age, you can't afford to have data offline nor can your team afford to spend hours maintaining and managing storage to ensure it remains resilient. Nutanix AOS Storage is designed to be dynamic, intelligent, and resilient, delivering consistent low latency even during failures.

Nutanix AOS Storage is fault-tolerant, with no single points of failure and no bottlenecks that slow down performance. AOS Storage is self-healing as it detects, isolates, and recovers from failures; survives system hardware, software, and hypervisor issues; and maintains high data availability using cluster resiliency, data resiliency, and availability domains.

Cluster Resiliency

A Nutanix cluster administrator can set the fault tolerance (FT) level for each cluster, specifying the number of simultaneous failures a cluster can withstand. A failure could be any component within a node such as a drive or network interface, or an entire node.

- **Fault Tolerance Level 1 (FT 1).** Cluster can tolerate one failure at any time.
- **Fault Tolerance Level 2 (FT 2).** Cluster can tolerate two concurrent failures at any time.

FT1 requires three copies of metadata, while FT2 requires five copies. An existing cluster can be promoted from FT1 to FT2 if all conditions are met.

Data Resiliency

AOS Storage leverages replication factor (RF), also known as tunable redundancy, to ensure data redundancy and availability in the face of node or drive failures. This RF value can be set to one, two, or three. Upon write, data is synchronously replicated to another node (RF2) or two other nodes (RF3) before the write is acknowledged as successful. This process ensures that the data exists in multiple independent locations for fault tolerance.

All writes are dynamically placed, with replicas placed based on the FT domain and other factors such as the storage and compute utilization of each node. There is no static binding that determines where a node's replicated data is placed. All nodes participate in replication, eliminating hot spots and ensuring linear performance scaling.
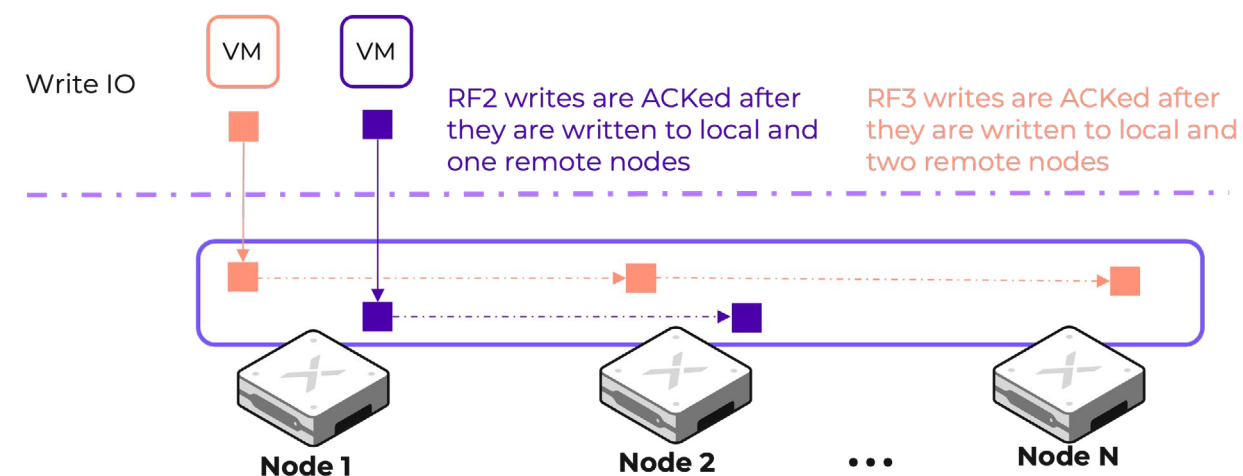
If there is a failure in the cluster, such as a node, disk, or CVM becoming unresponsive, AOS Storage can quickly and easily determine which data copies are no longer available thanks to the distributed metadata store and immediately start the rebuild process. Data is automatically read from other nodes in the cluster. If the node does not come back online, all affected data is automatically rebuilt from the other copy or copies to ensure full redundancy and data resilience are restored without requiring operator intervention. Because of the distributed architecture and intelligent copy placement, recovery from failure occurs across multiple nodes and drives, preventing hot spots.

Availability Domains

Availability domains intelligently distribute data, metadata, and Nutanix configuration information to further increase resilience. By default, AOS Storage provides disk awareness and node awareness. Data replicas are placed such that two copies are never on the same disk or node. AOS Storage can also provide block awareness (a block is a multi-node enclosure) and rack awareness. These options ensure that data copies are not placed on the same block or the same rack, respectively, for protection against power failures, cooling problems, etc.

- **Block Awareness** allows a cluster to lose one (RF2) or two (RF3) multi-node enclosures without impacting data availability. It is automatically enabled on a best-effort basis with a minimum of three blocks necessary for block awareness to be active.

- **Rack Awareness** allows a cluster to lose one (RF2) or two (RF3) complete racks (potentially housing multiple blocks/nodes) without impacting data availability. It requires additional configuration effort from an administrator to map the physical locations of nodes across racks since rack configuration cannot be determined by software alone.

When distributing data:

- AOS Storage makes a placement decision for each data copy independently.
- One copy is always local to the node where the application is running.
- Other copies are spread equally across the cluster based on availability domain configuration.
- Data is automatically moved between nodes and between tiers by AOS Storage when a VM moves.
- During failures, rebuild of data copies is performed immediately to protect data availability allowing Nutanix clusters to self-heal and lessening the urgency of replacing failed drives and other components.

These rules allow a Nutanix cluster to provide better resilience and performance while reducing the amount of manual intervention required.
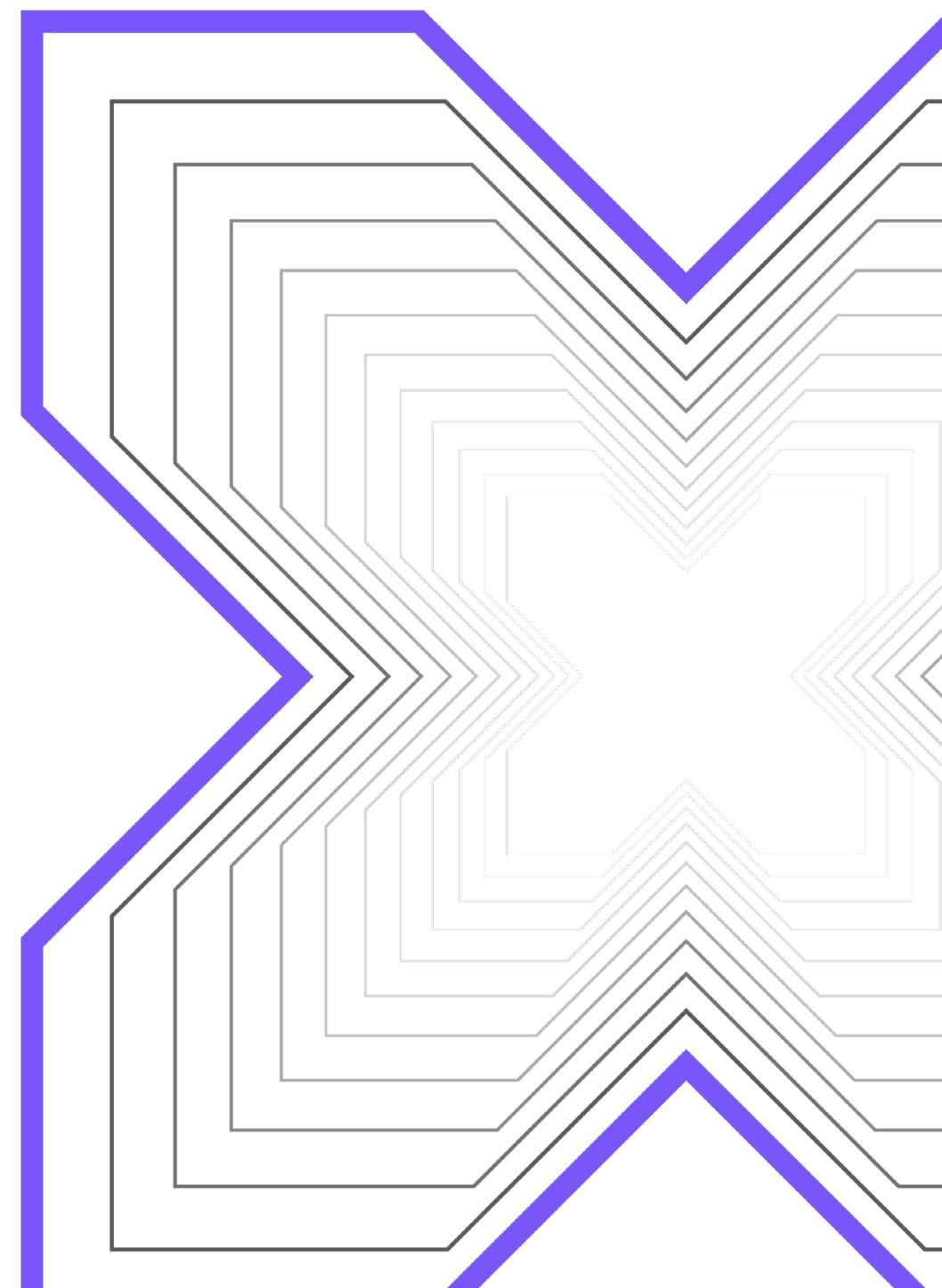
AOS Storage: Performance

With SAN storage, administrators often dedicate a lot of time and effort to performance tuning, and different types of arrays may be needed to satisfy different storage needs. AOS Storage has many built-in capabilities that automatically enhance performance and adapt to workload needs. This helps make sure that every Nutanix cluster delivers optimum performance for every workload, so you waste less valuable time monitoring and tuning performance. Notable capabilities include:

- Application and VM-aware data placement
- Intelligent data tiering
- Data locality
- Autonomous extent store

And Nutanix never rests on its laurels, we continue to add capabilities to further enhance performance and scale.

Intelligent Tiering

Intelligent Tiering provides automatic performance optimization on systems with multiple storage tiers (NVMe, SSD, HDD). Data is assigned to different tiers of storage within the storage pool using information lifecycle management (ILM) algorithms. Hot data is always preferentially targeted to the fastest storage tier. AOS Storage continually monitors data access patterns and optimizes data placement on the most appropriate tier, achieving the best performance without tuning. A local node's NVMe or SSD drives are always the highest priority for I/O generated on that node, but all a cluster's SSD resources are available to all nodes within a cluster.

Data Locality

AOS Storage is designed to ensure that every VM's data is served locally from the CVM and that one copy is always written on the local node where the VM is running. This provides consistent performance for applications by minimizing network chatter and eliminating the need for network hops for data access. Data that is not local, a condition that can occur when a VM is migrated from one node to another, is moved to the local node on subsequent reads.

Autonomous Extent Store

The Autonomous Extent Store (AES) improves on the original AOS Storage Extent Store implementation. AES provides higher sustained random-write performance via metadata locality:

- Reduces on-disk writes by up to 40%
- Reduces network utilization for data access by up to 75%
- Lowers CPU utilization

Advanced Performance Options

Nutanix has been continuously evolving the AOS Storage architecture for performance and scale. Our goals include improvements to better support modern application demands, reduced total cost of ownership (TCO), increased density, and accelerating the pace of innovation. This section looks at several performance optimizations that take advantage of advanced hardware features or that support high-performance use cases such as databases.

RDMA

Remote Direct Memory Access (RDMA) improves latency by enabling direct data transfer between CVMs. Eliminating TCP/IP and hypervisor overhead reduces latency and CPU. With supported network hardware, RDMA can be used to replicate data directly between hosts using the iSCSI Extensions for RDMA (iSER). This increases throughput for latency-sensitive applications like SAP HANA and Kafka. RDMA configuration has been greatly simplified, lowering the barrier to adoption.
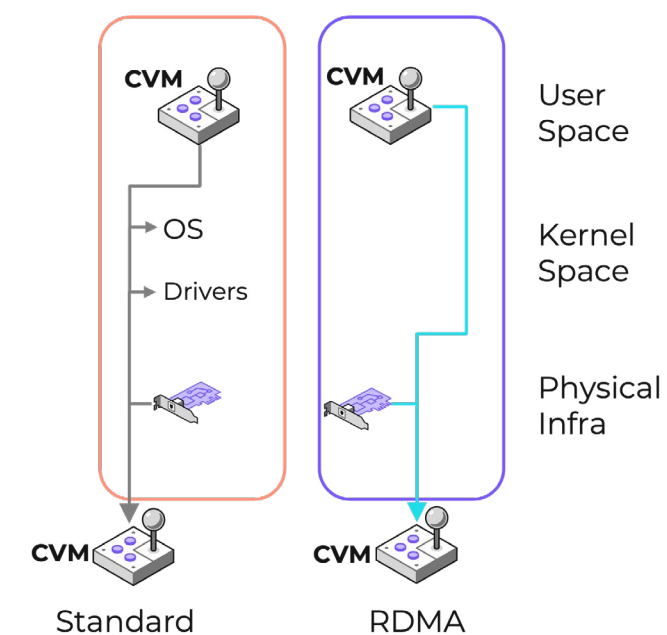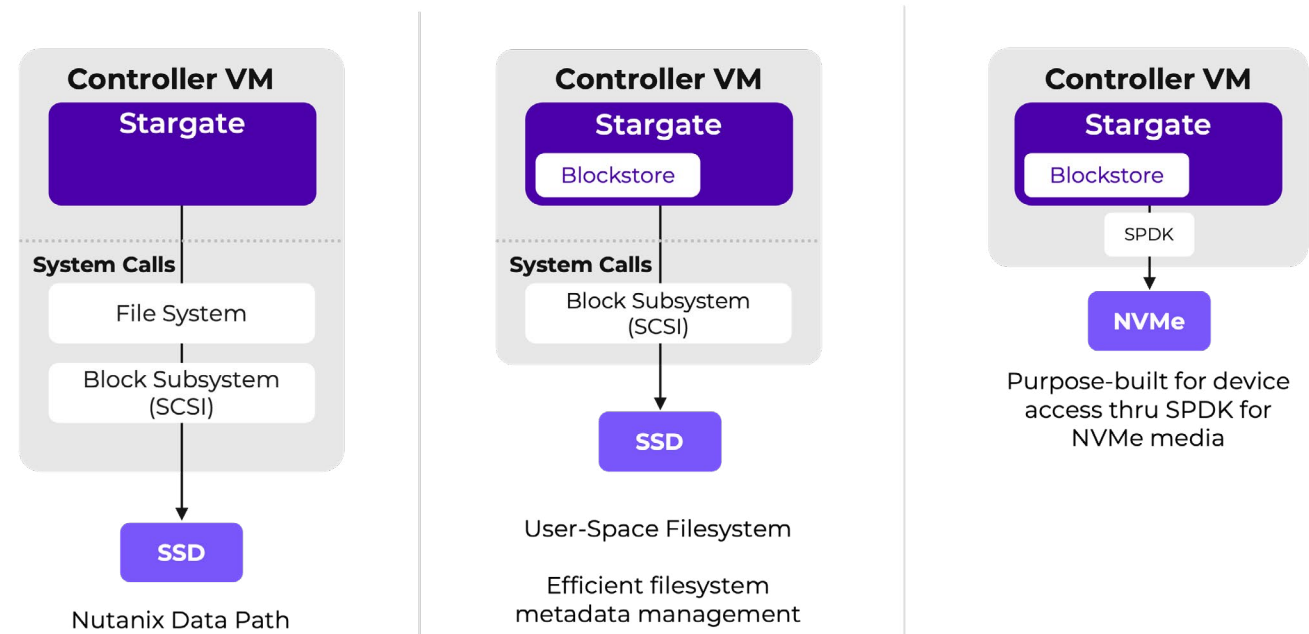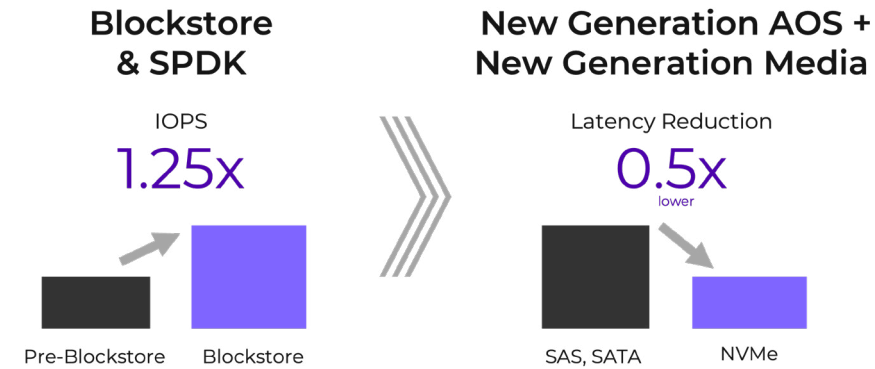
Blockstore and SPDK for NVMe

Nutanix Blockstore is a user-space filesystem for the Extent Store that works with all supported hypervisors. Moving device interactions into user space eliminates context switching and kernel driver invocation, enabling AOS Storage to fully utilize the performance of the latest media. AOS Storage uses the Intel Storage Performance Development Kit (SPDK) for zero-copy, direct parallel access to NVMe devices, unlocking their potential. Blockstore combined with SPDK makes the AOS Storage data path inside the CVM very lean, delivering performance benefits for applications, including:

- Ultra-low latency
- Higher performance
- Greater CPU efficiency

Blockstore & SPDK

IOPS

1.25x

Pre-Blockstore   Blockstore

New Generation AOS + New Generation Media

Latency Reduction

0.5x
lower

SAS, SATA   NVMe

Controller VM

Stargate

System Calls

File System

Block Subsystem (SCSI)

SSD

Nutanix Data Path

Controller VM

Stargate

Blockstore

System Calls

Block Subsystem (SCSI)

SSD

User-Space Filesystem

Efficient filesystem metadata management

Controller VM

Stargate

Blockstore

SPDK

NVMe

Purpose-built for device access thru SPDK for NVMe media

Database Optimizations

A common misconception about HCI is that it's not suited for high-performance database needs. However, Nutanix HCI has been optimized from early in our history for database workloads and we continue to add features to enhance database performance. Nutanix delivers the performance, scalability, and manageability you need to operate the most complex database environments at peak performance.

Three recent enhancements that can be employed to further optimize database performance are described below.

RF1

Certain applications such as Hadoop and SAS Analytics provide resiliency at the application level, and some traditional databases such as Microsoft SQL Server store data temporarily. In such cases, there is no need for data resilience at the platform level using RF2 or RF3. For these use cases, AOS Storage now supports Replication Factor 1 (RF1), meaning data is not replicated for redundancy.

RF1 provides two benefits:

1. **Greater storage efficiency.** Since no replicas are created, less physical storage is needed.

2. **Performance gains.** I/O write performance is improved because data doesn't need to be replicated across the network, providing data locality for writes. For example, Cloudera completion times are 3X faster with RF1. SAS Analytics throughput increases by 2.5x.

Single vDisk

In virtual environments, databases are often configured with a single vDisk. Enabling vDisks to be accessed by multiple vDisk controller threads through vDisk sharding. In AOS Storage 6.1 and later, the vDisk controller has been modified so that requests to a vDisk are distributed across multiple shard vDisk controllers managed by the primary vDisk controller, effectively sharding the single vDisk. This results in significant performance improvements:

- 2X for single vDisk with multiple data files
- 1.8X for single vDisk with single data file
- 18-20% for multiple-vDisk configs

The single vDisk enhancement makes it possible to lift and shift SQL Server instances and similar databases from legacy infrastructure to Nutanix with no configuration changes. However, the use of multiple vDisks for a VM remains the best practice for realizing all the performance benefits of our scale-out architecture.

Single I/O thread between vDisk and CVM

Multiple I/O threads between vDisk and CVM
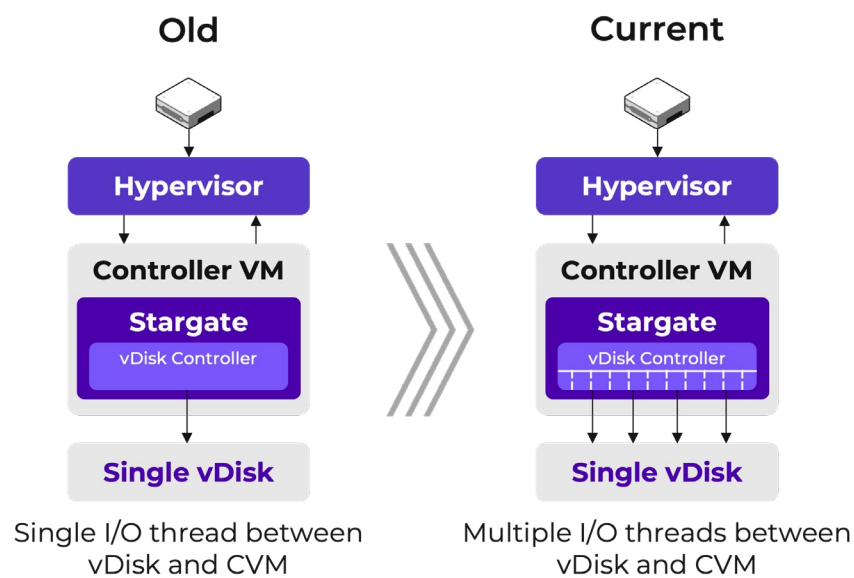
Optimized Database Solution

Some commercial databases utilize per-core licensing. If you use these databases, you want to ensure that CPU cycles are used optimally to minimize the number of cores you must license. Nutanix has introduced an Optimized Database Solution that combines compute-only and storage-only nodes to maximize the CPU power dedicated to database processing, thereby minimizing per-core licensing costs. Licensing databases to run on compute-only nodes moves storage processing to storage-only nodes without impacting database performance, ensuring that compute and storage can be scaled completely independently.

Performance for Diverse Use Cases and Nutanix Unified Storage

In practice, Nutanix customers find AOS Storage performance to satisfy their performance needs for a wide range of workloads ranging from end-user computing (EUC) environments to modern, containerized applications to high-performance databases. Many customers find that Nutanix offers better performance than legacy 3-tier infrastructure, reducing execution times for long-running processes while dramatically simplifying management.

From the beginning, Nutanix customers found AOS Storage to be so performant and simple to manage that they asked Nutanix to layer on support for file services to take the place of NAS devices, block services to take the place of SAN arrays and flexible object stores. Today, the capabilities of AOS Storage provide the foundation of Nutanix Unified Storage (NUS).

NUS offers a unified platform for File, Object, and Block storage with flexible, capacity-based licensing across all data services. A single Nutanix cluster can support data services alongside other workloads, and many customers prefer to dedicate specific clusters for data services. Either approach eliminates the cost and complexity of managing separate NAS systems, file servers, and SANs, dramatically simplifying your IT environment and lessening the burden on already stretched IT teams.

AOS Storage: Data Efficiency

AOS Storage incorporates a wide range of data efficiency technologies that work in concert to make the most efficient use of the available storage capacity in a Nutanix cluster. These technologies are intelligent and adaptive to workload characteristics, eliminating much of the need for manual configuration and fine-tuning.

Data Compression

Compression saves physical storage space and improves I/O bandwidth and memory usage—which can have a positive impact on overall system performance. As with most tasks in a Nutanix cluster, compression is a distributed process that runs across every node. Overall compression power scales as the cluster grows. There are two types of data compression integral to AOS Storage:

1. **Inline compression.** Enabled by default, sequential streams of data or large I/Os are compressed as they are written to the Extent Store. This approach utilizes OpLog capacity efficiently and helps drive sustained performance.

2. **Post-process compression.** Data is initially written in an uncompressed state. A background process periodically compresses data cluster-wide, eliminating any impact on write latency.

Inline Compression I/O Path
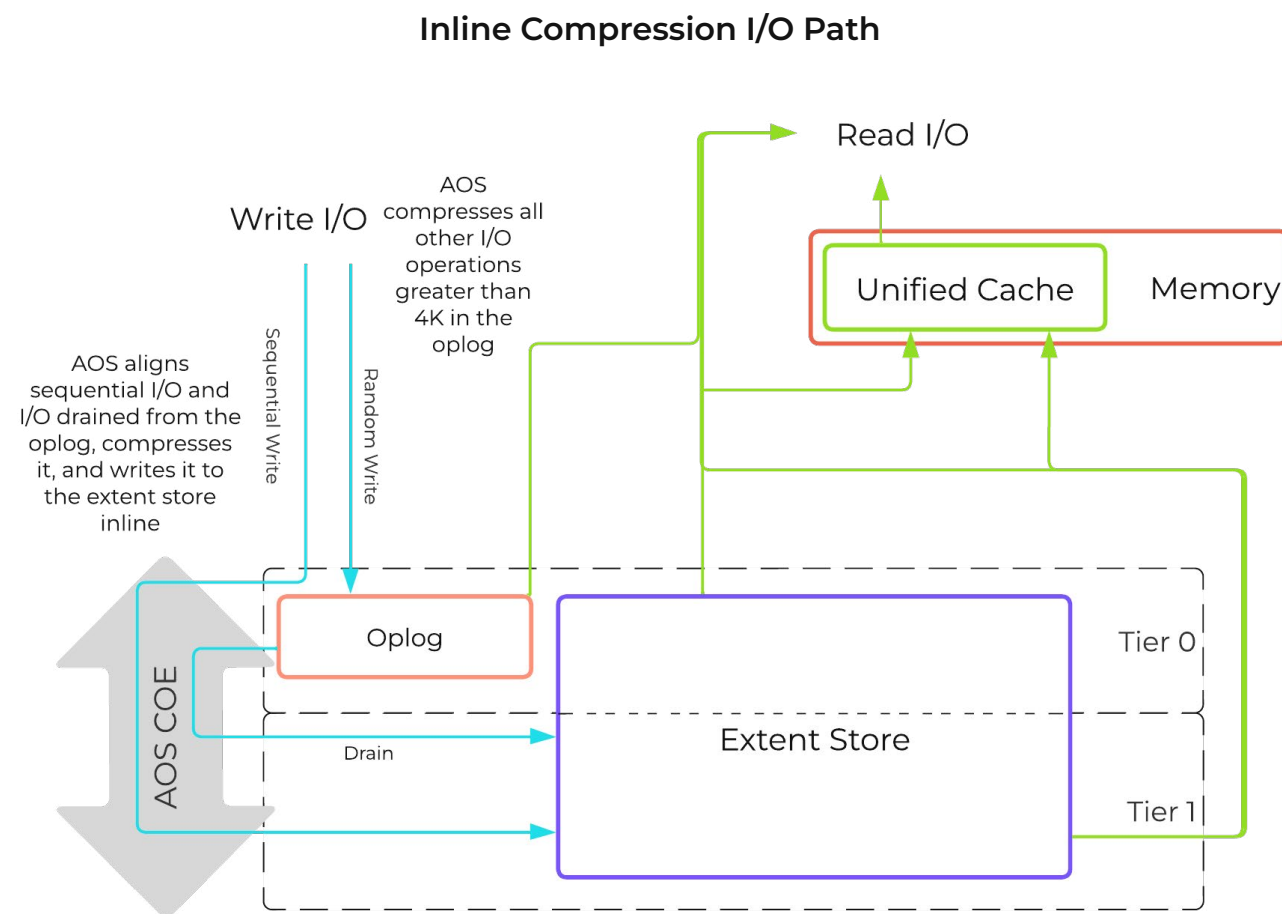
Deduplication

The Elastic Deduplication Engine is a software-based feature that deduplicates data in the extent store. Unlike traditional approaches, which use background scans that read data again, the Elastic Deduplication Engine stores fingerprints persistently as part of a written block's metadata. The stored fingerprints allow the Elastic Deduplication Engine to detect and remove duplicate copies easily without scanning or reading the data again.

At ingest, the Elastic Deduplication Engine fingerprints data streams of 64 KB or more at a 16 KB granularity, using logical checksums to select candidates for dedupe. Starting with AOS 6.6, the algorithm has been enhanced so that in every 1 MB extent, only chunks with duplicates are marked for deduplication, significantly reducing the metadata required for dedupe.

After AOS Storage marks the duplicate chunks for deduplication, the Curator MapReduce framework removes those chunks. Automatic resource adjustments ensure that deduplication tasks don't limit the performance of user applications.

Erasure Coding

AOS Storage uses an innovative erasure coding technology that increases usable capacity significantly without affecting resilience. It encodes a strip of data blocks on different nodes and calculates parity. In the event of a disk or node failure, parity is used to calculate any missing data blocks. The number of data and parity blocks in a strip is configured based on the number of failures you want the system to be able to withstand.

## Elastic Deduplication Engine I/O Path
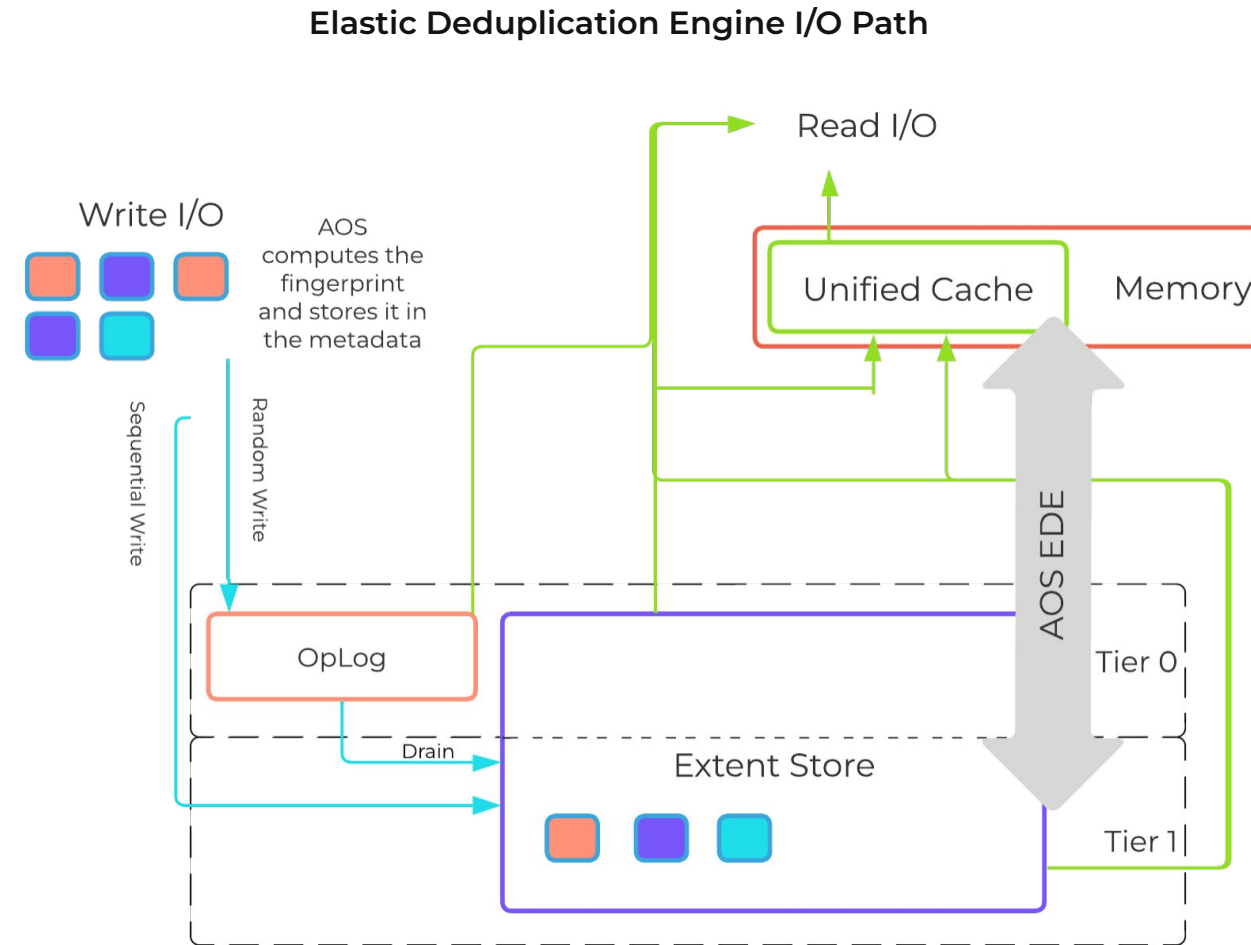
Since coding and rebuilds are distributed across the entire cluster, Nutanix erasure coding is highly efficient with minimal computational overhead. This reduces vulnerability windows in the event of failures by speeding up rebuilds. It also maintains data locality for high performance. Post-processing is used for erasure coding, and only operates on write-cold data (no writes for 7 days or more). Unlike deduplication and compression, which vary in efficacy depending on the data characteristics, erasure coding offers deterministic capacity savings.

Snapshots and Clones

Full data copies are a significant waste of storage capacity. AOS Storage provides space-efficient snapshots and clones that can eliminate the need for making full copies of VMs or vDisks for data protection, testing, or other purposes.

The same general methods are used for both snapshots and clones. The current block map for the object to be snapshotted or cloned is locked, and the copy is created. This is accomplished with metadata only, so no I/O takes place. A snapshot is a point-in-time copy that is not writeable, while a clone can be written to. Snapshots are most often used for data protection. Clones are useful for making many executable copies of a VM, or for creating a writable copy of a data set (for example for testing) without requiring a full copy.
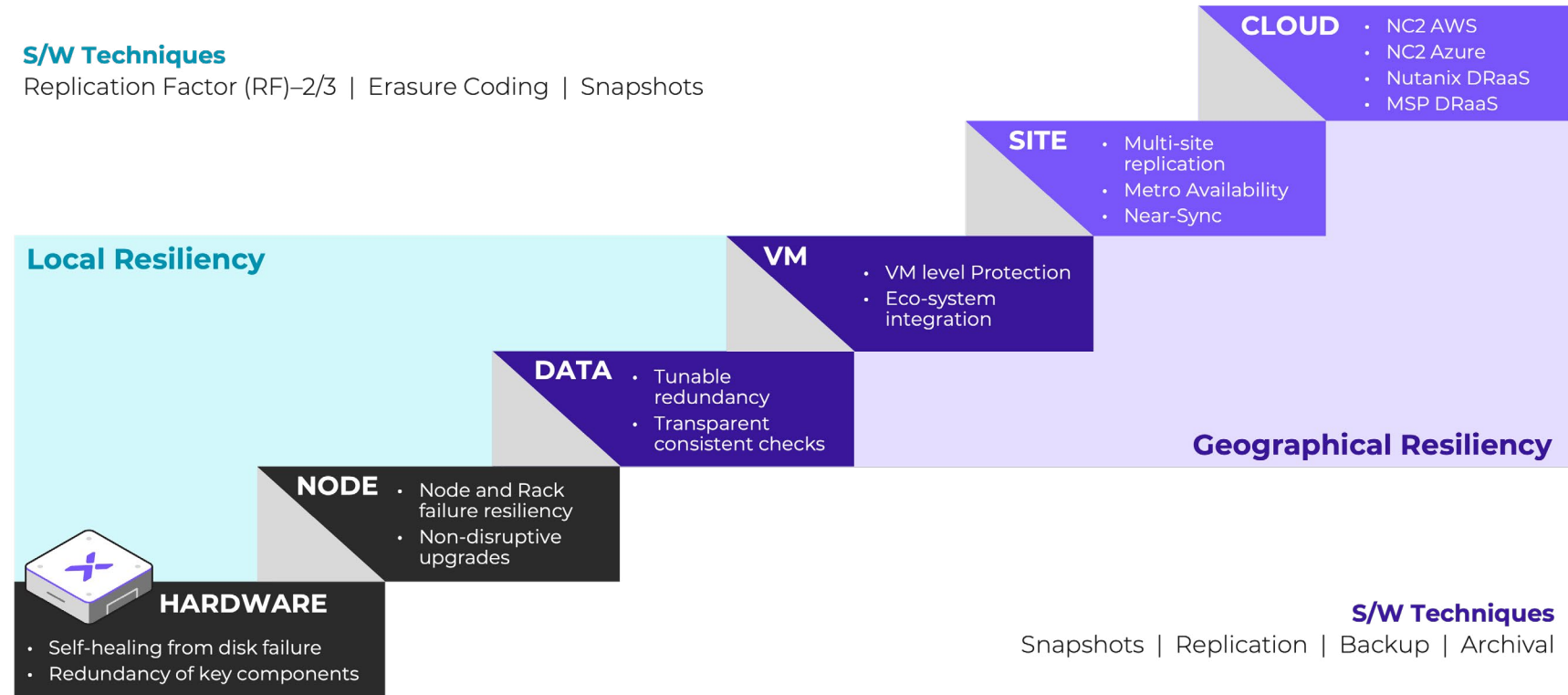
Example Clone Block Map
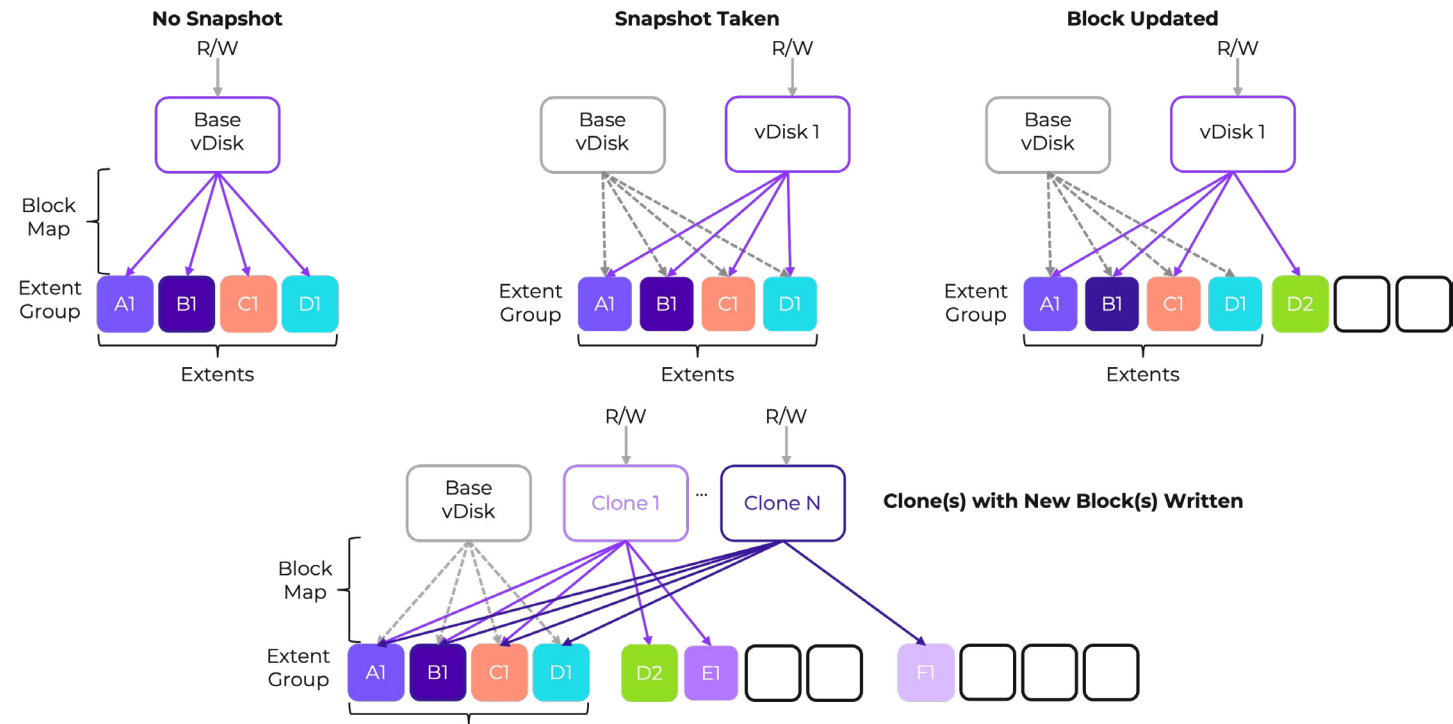
AOS Storage: Backup and Disaster Recovery

Data protection and disaster recovery can be a significant pain point for most IT teams, consuming significant admin time and storage capacity, and requiring specialized add-on software. AOS Storage integrates essential capabilities, providing a foundation for protection at every level, greatly simplifying your operations while providing a higher level of protection.

S/W Techniques
Replication Factor (RF)–2/3 | Erasure Coding | Snapshots

CLOUD
- NC2 AWS
- NC2 Azure
- Nutanix DRaaS
- MSP DRaaS

SITE
- Multi-site replication
- Metro Availability
- Near-Sync

VM
- VM level Protection
- Eco-system integration

DATA
- Tunable redundancy
- Transparent consistent checks

Local Resiliency

Geographical Resiliency

NODE
- Node and Rack failure resiliency
- Non-disruptive upgrades

HARDWARE
- Self-healing from disk failure
- Redundancy of key components

S/W Techniques
Snapshots | Replication | Backup | Archival

In today's digital world, organizations struggle with three major data protection and DR challenges:

- Ensuring that backups and recoveries are fast and reliable—without introducing unnecessary operational complexity
- Guaranteeing business continuity in the face of natural and manmade threats
- Protecting against ransomware and other cybercrime

AOS Storage integrates and simplifies data protection to address these challenges, delivering the capabilities that are essential for cyber resilience and data protection. Advanced availability and data protection capabilities include integrated snapshots and clones, automated failover, flexible replication options, and integrations with the leading backup ISVs.

AOS Storage offers integrated tools that protect at multiple levels:

- **On-cluster snapshots** provide a first line of defense and the fastest and most convenient recovery.
- **Remote backup** replicates snapshots to a remote Nutanix cluster (Async or NearSync) for longer-term retention and site-level resilience.
- **Metro Availability** synchronously replicates data to another site, ensuring that a real-time copy of the data exists at a different location for workloads requiring zero RPO and near-zero RTO. During a disaster or planned maintenance, VMs can fail over from a primary site to a secondary site, guaranteeing nearly 100 percent uptime.
- **Cloud backup** uses a public cloud as a remote backup target.

AOS Storage also integrates with popular third-party backup vendors to create a turnkey solution for backup and recovery.

Disaster Recovery

Nutanix Disaster Recovery is a natively integrated DR solution included with the Nutanix Cloud Platform that helps you minimize data loss and downtime should disaster strike. This solution helps you design disaster recovery plans that meet the specific needs of your applications. With options that include recovery on-prem, to a public cloud, to an MSP, and disaster recovery-as-a-service (DRaaS), Nutanix DR offers one-click failover, failback, and automated recovery—so you can meet SLAs while eliminating data silos and reducing TCO.

AOS Storage: Platform Security

The Nutanix Cloud Platform (NCP) provides a unified, layered approach to cybersecurity across its platform, data, networks, applications, and current security vendor solutions. Together, these help to build strong cyber resilience in the face of constant threats. Aligned to the NIST Cybersecurity Framework (NIST CSF), NCP provides built-in capabilities to:

· Govern: Establish and monitor the organization's cybersecurity risk management strategy, expectations, and policy.

· Identify: Use safeguards to prevent or reduce cybersecurity risk.

· Protect: Help determine the current cybersecurity risk to the organization.

· Detect: Find and analyze possible cybersecurity attacks and compromises.

· Respond: Take action regarding a detected cybersecurity incident.

· Recover: Restore assets and operations that were impacted by a cybersecurity incident.

Cyber resilience is the centerpiece of a modern cybersecurity strategy. As cyberattacks become more frequent, refined and harder to detect, sensitive data is more vulnerable than ever. Your security tactics must evolve to address a growing number of security challenges, including:

· Increasing private, hybrid, and public cloud complexity

· Growing frequency and sophistication of cyberattacks

· Reliance on manual security controls that impact operational agility and increase risk

· Hybrid Multicloud (on-premises, single, and multiple public cloud) environments with different security controls in each environment

Nutanix AOS Storage streamlines security operations with built-in security solutions designed to harden your platform (infrastructure), data, networks, and applications, while integrating with your existing security investments.

Self-Healing Security

AOS Storage platform security begins with intelligent software designed to automate and operate critical security controls. These functions improve your security posture, help to detect security threats, prevent breaches, and prevent data loss while minimizing disruptions to ensure business continuity.

Nutanix incorporates industry best practices and government standards into a system that automates the configuration and monitoring of a secure baseline. Nutanix software self-heals when an anomaly is found, helping you achieve your security and compliance goals effortlessly.

Nutanix has developed security hardening guides—based on the US Department of Defense (DOD) Security Technical Implementation Guide (STIG) frameworks—that are easy to maintain and machine-readable. Nutanix software automatically configures itself without a lot of tedious manual settings that may result in errors and misconfigurations.

Regular health checks of an applied STIG baseline are performed automatically and—if a system is found non-compliant—the baseline settings are reset and reapplied, so that a hardened system remains compliant, reducing the risk of manual misconfigurations and configuration drift.
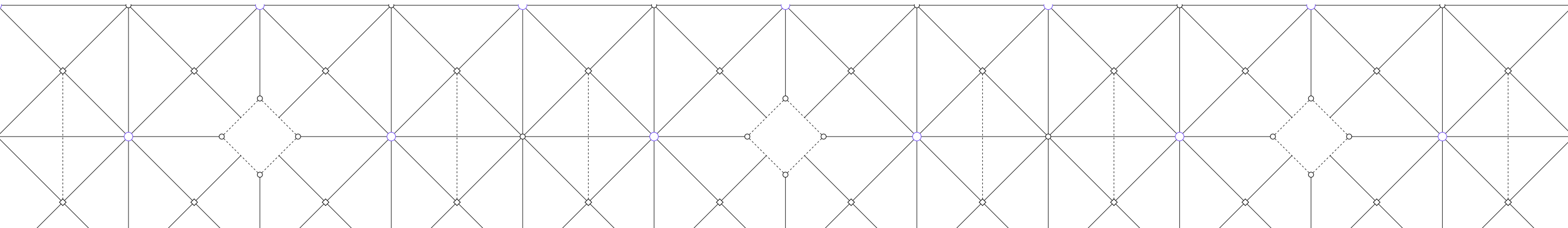
Encryption

Not all data may be created equal, but—given the heightened risks of ransomware, data exfiltration, and other cyber threats—all data needs protection. Nutanix provides flexible data-at-rest encryption using a variety of methods so you can meet all your security and compliance requirements securely and cost-effectively. Encryption options include self-encrypting drives (SED) for situations that require them and software encryption. For encryption key management, Nutanix lets you choose between an External Key Manager (EKM) and our native key management server (KMS).

Move Between Options in Real-Time
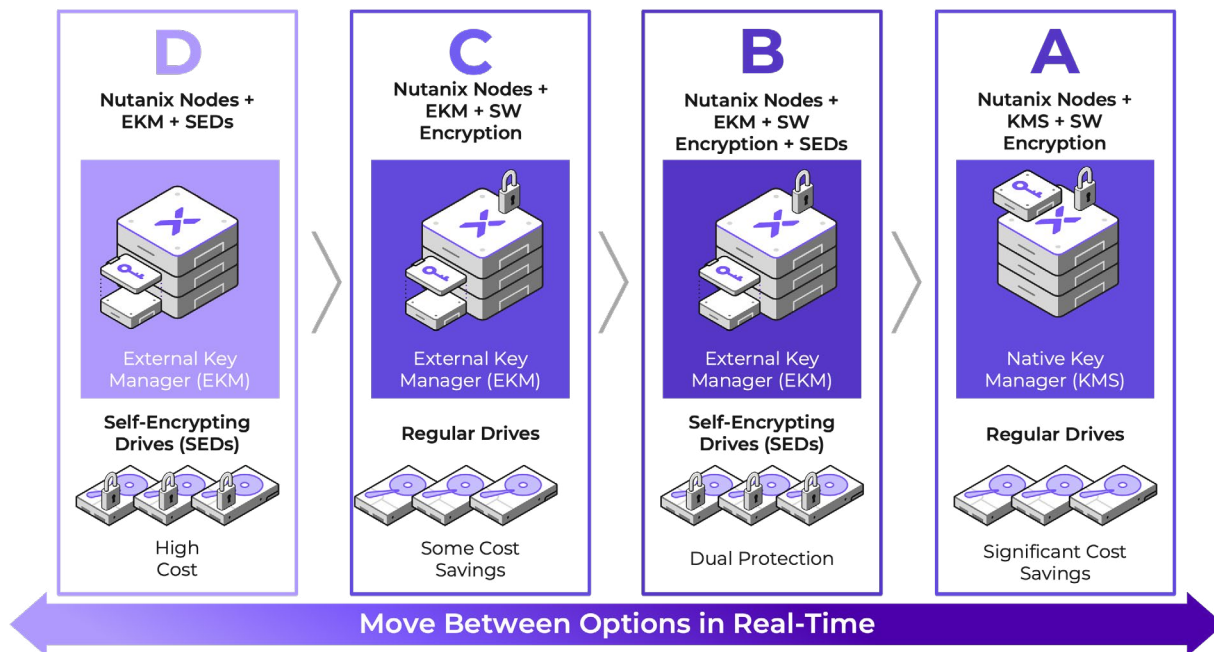
Using software encryption, you can set fine-grained policies to encrypt VMs or groups of VMs.

Identity Access Management

Identity and access management (IAM) is necessary to secure access to applications, storage, and other resources. IAM involves authentication and authorization of identities for all users, applications, or services that require access to these resources. AOS Storage offers several tools to ensure IAM is enforced:

- **Multi-factor Authentication (MFA) via SAML 2.0.** Nutanix supports SAML integration and optional multi-factor authentication for system administrators in environments requiring additional layers of security. When implemented, administrator logins require a combination of a client certificate and username and password.

- **Role-Based Access Controls.** When an identity attempts to access a resource, RBAC checks its role and the policies assigned to that role to determine if the identity has permission to access the resource. If the identity does not have permission, it is denied access to the resource. AOS Storage provides role-based access control (RBAC) through a variety of mechanisms, including:

  - **Roles.** Roles define the permissions that specific identities have to access Nutanix resources. Roles can be assigned to individual users or groups of users.
  - **Policies.** Policies define the actions that can be performed on Nutanix resources. Policies can be assigned to roles.
  - **Objects.** Objects are the resources that can be accessed, such as VMs, hosts, and containers. Objects can be assigned to policies.

Logging

AOS Storage provides complete policy and event auditing to satisfy compliance requirements and to enable your security team to quickly identify policy violations and possible security events.

# AOS Storage: Configurations and Manageability

Nutanix and its OEM partners offer a variety of nodes with different compute and storage configurations to meet your needs. Available options range from compute-only, to compute-heavy, to storage-heavy, to storage-only. All nodes containing storage must contain SSD or NVMe. Nodes are available in hybrid (SSD or NVMe + HDD), all-SSD, or all-NVMe configurations. You can combine nodes with different capabilities in a single cluster to address specific needs.

- **Compute-only nodes.** Compute-only nodes allow you to scale compute resources without adding additional storage capacity. This can be useful for workloads that may not require a lot of storage, such as VDI. By using compute-only nodes, you can grow the compute performance of a cluster without scaling capacity.

- **Storage-only nodes.** Storage-only nodes allow you to add storage capacity without adding compute resources. This is useful for workloads that have significant storage requirements, such as big data and large object stores. By using storage-only nodes, you can significantly scale the storage capacity of a cluster independent of compute.

As noted earlier, a combination of compute-only and storage-only nodes can be used to reduce the licensing costs for databases that are licensed on a per-core basis. Compute-only nodes do not have CVMs. All I/O requests are forwarded to CVMs on storage-only nodes, so compute-only nodes (where your databases run and are licensed) maximize the use of CPU cycles for the database.

Manageability

The management of AOS Storage is an integral part of Nutanix management tools. IT generalists can manage all the storage functionality described in this eBook from an intuitive interface that uses thoughtful design and machine intelligence to enable one-click operations. Nutanix also offers a full command line interface (CLI) and a complete set of APIs for those who prefer to utilize scripts or want to integrate AOS Storage capabilities in their code.
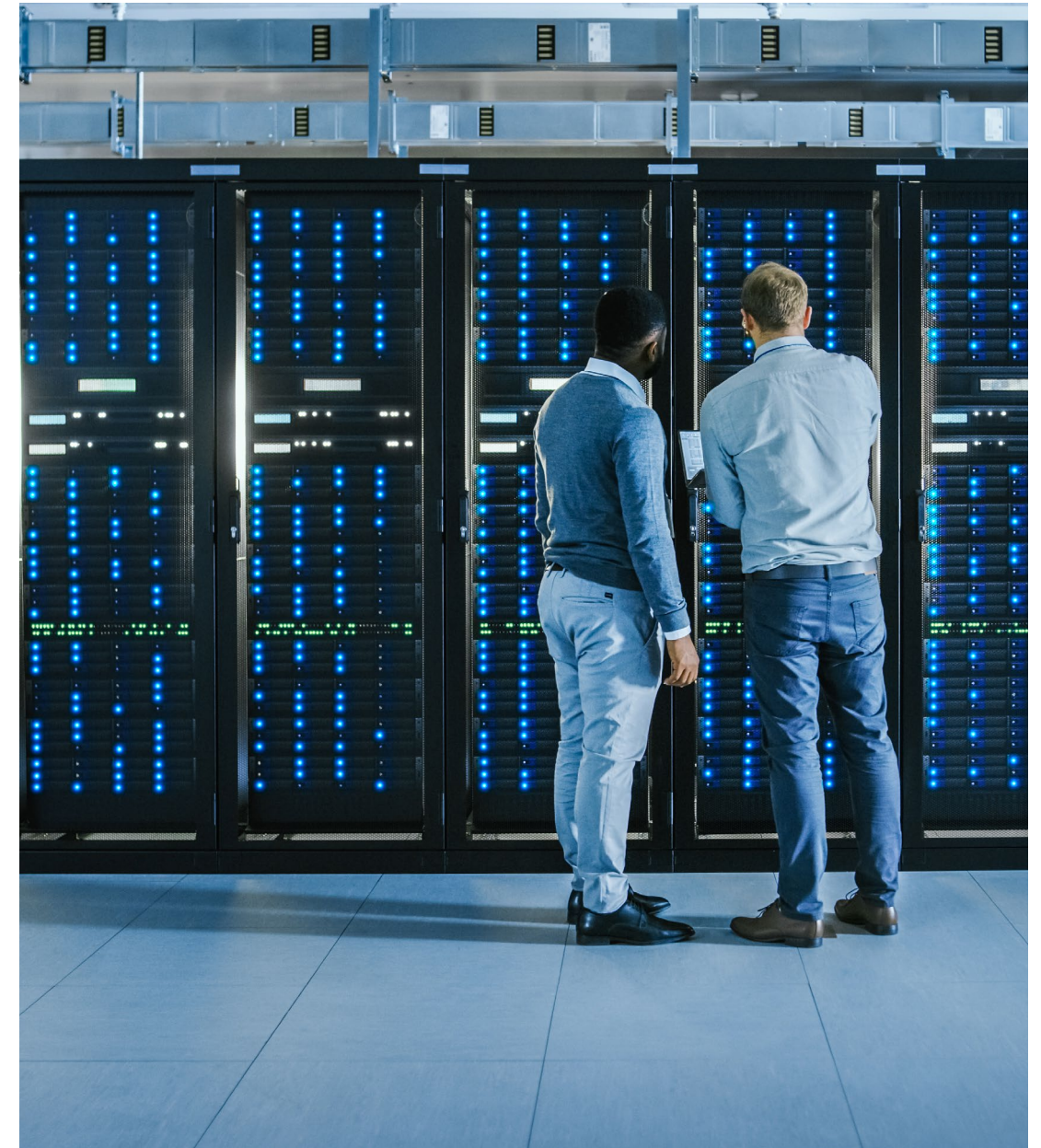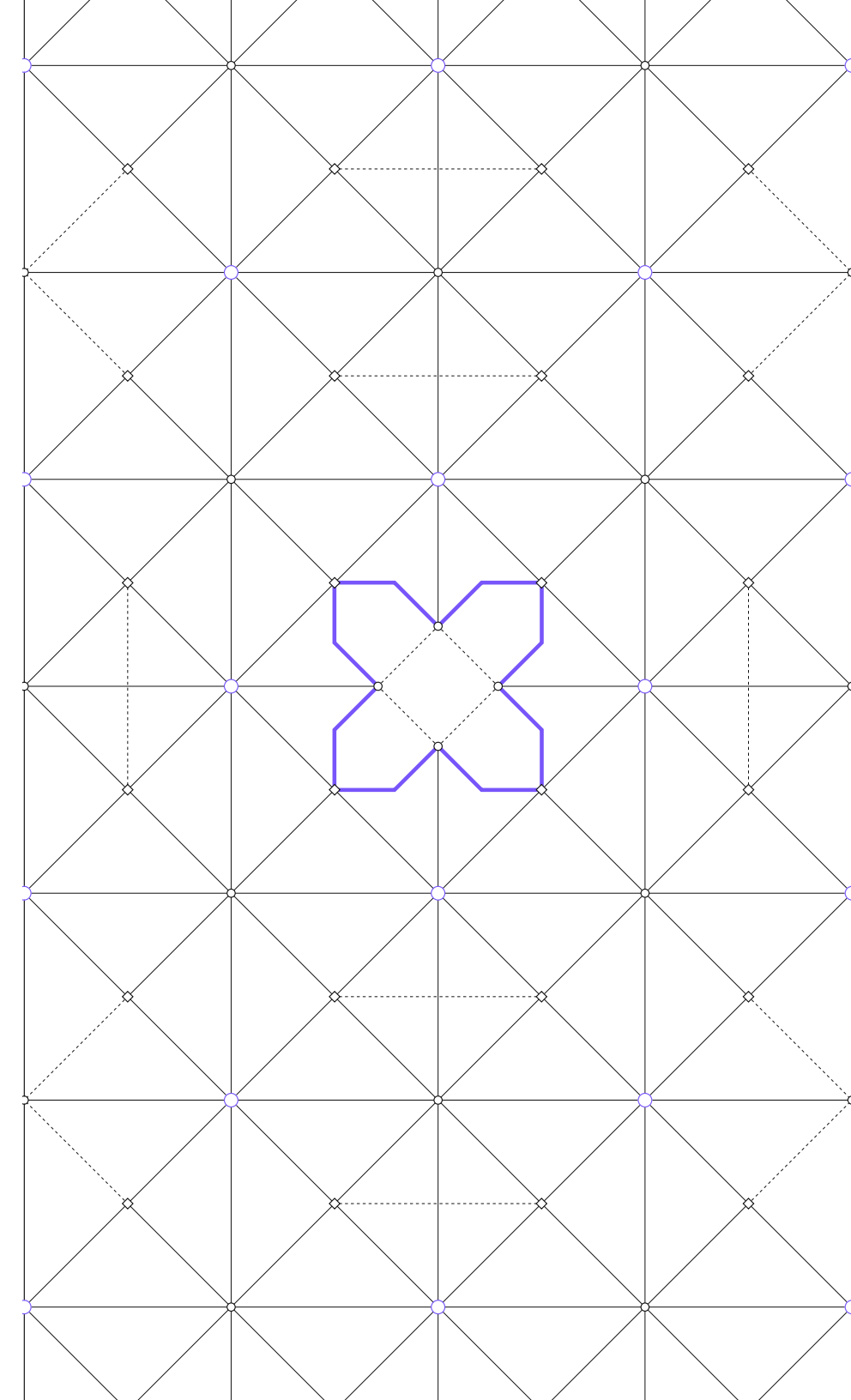
AOS Storage or SAN

Now that you've learned about AOS Storage's many capabilities, it's worth thinking about how AOS Storage stacks up against traditional storage solutions.

Relying on traditional SAN-based infrastructure to support modern application needs can limit the flexibility and agility of your IT environment. You likely have dedicated silos of infrastructure that are optimized for specific use cases. For example, you may have dedicated infrastructure for virtual desktop infrastructure (VDI) deployments to prevent issues such as boot storms or recompose operations from negatively impacting other critical workloads such as databases. This fragmentation prevents resources from being shared or easily re-purposed and makes it difficult to achieve economies of scale, hampering productivity, slowing down projects, and increasing infrastructure and management costs.

With SAN, the storage layer is accessed across the network. Each server connects to a centralized storage array, typically with at least two storage controllers in an active-active or active-passive configuration. All storage I/O travels across the storage network (either IP or Fibre Channel), and through one or both storage controllers before reaching physical storage devices.

As you add more workloads, storage controllers can become a bottleneck due to storage contention issues and scalability limits. Traditional storage arrays are large, expensive purchases and require extensive planning to avoid under or over-provisioning. This planning process consumes large amounts of staff resources, makes it difficult to react quickly to new initiatives, and is often imprecise due to the long timeframes involved.

In addition, the hypervisor, servers, network, and storage may all be managed and operated by separate teams, further hampering business agility and complicating troubleshooting. As you've learned, AOS Storage eliminates most of these challenges, scaling in lockstep with your needs and avoiding the typical forklift upgrades that occur every 3-5 years in SAN environments. Nutanix also takes the place of your existing SAN arrays for legacy, bare-metal applications that require block access. Plus, Nutanix replaces existing NAS systems and can provide scalable object storage to address object use cases.

Getting Started with AOS Storage

The flexibility, resilience, and performance of AOS Storage are integral to the success of Nutanix Cloud Platform (NCP), whether running on-premises, at the edge, or in a public cloud. With Nutanix, you get the same great storage experience with the same simple management across your entire hybrid multicloud environment. If you're ready to experience NCP and AOS Storage firsthand, you can take a test drive:

Take a Test Drive

Visit our AOS Storage page and Nutanix Cloud Infrastructure page to learn more. There you'll find videos and other information that will help you learn more. You can also contact Nutanix at info@nutanix.com, follow us on Twitter @nutanix, or send us a request at www.nutanix.com/demo to set up your own customized briefing.

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