Technical White Paper

Dell EMC SC Series: Synchronous Replication and Live Volume

Abstract

This document provides descriptions and use cases for the Dell EMC SC Series data protection and mobility features of synchronous replication and Live Volume.

December 2020

Revisions

Date	Description
May 2014	Merged synchronous replication and Live Volume documents; updated for Enterprise Manager 2014 R2 and SCOS 6.5
July 2014	vSphere HA PDL update
November 2015	Updated for SCOS 6.7
July 2016	Updated for SCOS 7.1 and DSM 2016 R2
October 2016	Minor updates
February 2017	Updated guidance on MPIO settings for Windows Server and Hyper-V
July 2017	Minor updates
December 2017	Minor updates to section 3.4.1
April 2018	Updated for SCOS 7.3 and DSM 2018
July 2019	Consistent snapshot and Live Volume updates
September 2019	Updated link
February 2020	Minor updates for vSphere 6.7
December 2020	Updated for DSM 2020 R1 and vSphere 7

Acknowledgments

Authors: Jason Boche, Marty Glaser, Mike Matthews, Dan Tan, Mark Tomczik, and Henry Wong

The information in this publication is provided “as is.” Dell Inc. makes no representations or warranties of any kind with respect to the information in this publication, and specifically disclaims implied warranties of merchantability or fitness for a particular purpose.

Table of contents

Executive summary

Preventing the loss of data or transactions requires a reliable method of continuous data protection. In the event of a disaster or unplanned outage, applications and services must be made available at an alternate site as quickly as possible. A variety of data mobility methods, including asynchronous replication, can accomplish the task of providing offsite replicas. Synchronous replication sets itself apart from the other methods by guaranteeing transactional consistency between the protected site and the recovery site.

While remote replicas have traditionally provided a data protection strategy for disaster recovery, the disaster itself and the execution of a disaster recovery (DR) plan involves a period of downtime for organizations. Replicas along with storage virtualization can provide other types of data mobility that fit a broader range of proactive high availability use cases without an outage.

This guide focuses on two of the main data protection and mobility features available with Dell EMC™ SC Series storage: synchronous replication and Live Volume. In this paper, each feature is discussed and use cases are highlighted where these technologies fit independently or together.

1 Introduction to synchronous replication

While SC Series storage supports both asynchronous and synchronous replication, this document focuses primarily on synchronous replication.

By definition, synchronous replication ensures data is written and committed to both the replication source and destination volumes in real time. The data is essentially written to both locations simultaneously. In the event that the data cannot be written to either of the locations, the write I/O will not be committed to either location, ensuring transactional consistency, and a write I/O failure will be issued to the storage host and application where the write request originated. The benefit synchronous replication provides is guaranteed consistency between replication sites resulting in zero data loss in a recovery scenario.

Dell Technologies advises customers to understand the types of replication available, their applications, and their business processes before designing and implementing a data protection and availability strategy.

1.1 Features of SC Series synchronous replication

Mode migration: Existing replications may be migrated to an alternate type without rebuilding the replication or reseeding data.

Live Volume support: Live Volumes may leverage any available type of replication offered with SC Series storage including both modes of synchronous (high consistency or high availability) and asynchronous.

Live Volume managed replication: Live Volume allows an additional synchronous or asynchronous replication to a third SC Series array that can be DR activated using Dell™ Storage Manager (DSM).

Preserve Live Volume (manual failover): In the event an unplanned outage occurs impacting availability of a primary Live Volume, the secondary Live Volume can be promoted to the primary Live Volume role manually using DSM.

Live Volume automatic failover: In the event an unplanned outage occurs impacting availability of a primary Live Volume, the secondary Live Volume can be promoted to the primary Live Volume role automatically.

Live Volume automatic restore: After Live Volume automatic failover has occurred, Live Volume pairs may be automatically repaired after the impacted site becomes available.

1.2 Synchronous replication requirements

Replicating volumes between SC Series systems requires a combination of software, licensing, storage, and fabric infrastructure. The following sections itemize each requirement.

1.2.1 Dell Storage Manager

Dell™ Storage Manager (DSM) 2018 or newer is required to leverage all available replication and Live Volume features.

1.2.2 Storage Center OS

Dell Storage Center OS (SCOS) 7.3 or newer is required to leverage all available replication and Live Volume features.

1.2.3 Licensing

Replication licensing, which includes synchronous replication and asynchronous replication, is required for each SC Series array participating in volume replication. Additionally, a Live Volume license for each array is required for all Live Volume features. With Dell EMC SC All-Flash storage arrays such as the SC5020F and SC7020F, the replication and Live Volume licensing are included.

1.2.4 Supported replication transport

SC Series systems support array-based replication using either Fibre Channel (FC) or iSCSI connectivity. A dedicated network is not required but a method of isolation for performance or security should be provided. Synchronous replication typically requires more bandwidth and less latency than asynchronous replication due to sensitivity of applications and end users where the impacts of high latency will be felt.

2 Data replication primer

Data replication is one of many options that exist to provide data protection and availability. The practice of replication evolved out of a necessity to address a number of matters such as substantial data growth, shrinking backup windows, more resilient and efficient disaster recovery solutions, high availability, mobility, globalization, cloud, and regulatory requirements. The common requirement is to maintain multiple copies of data and make them highly available and easily accessible. Traditional backup methods satisfied early data protection requirements, but this feasibility diminished as data sets and other availability constraints grew. Vanishing backup windows, ecommerce, and exponential growth of transactions brought about the need for continuous data protection (CDP). Replicas are typically used to provide disaster recovery or high availability for applications and data, to minimize or eliminate loss of transactions, to provide application and data locality, or to provide a disposable data set that can be internally developed or tested. At a higher level, data protection translates to guarding the reputation of an organization by protecting end-user data.

2.1 Replication methods

There are a number of replication approaches, but two methods stand out as highly recognized today: asynchronous and synchronous. SC Series arrays support a flexible variety of replication methods that fall in the category of asynchronous or synchronous.

2.1.1 Synchronous

Synchronous replication guarantees data consistency (zero data loss) between the replication source and destination. This is achieved by ensuring write I/O commitments at the replication source and destination before a successful write acknowledgement is sent back to the storage host and the requesting application. If the write I/O cannot be committed at the source or destination, the write will not be committed at either location to ensure consistency. Furthermore, a write failure is sent back to the storage host and its application. Application error handling will then determine the next appropriate step for the pending transaction. By itself, synchronous replication provides CDP. Coupled with hardware redundancy, application clustering, and failover resiliency, continuous availability for applications and data can be achieved.

Because of the method used in synchronous replication to ensure data consistency, any issues impacting the source or destination storage, or the replication link in-between, will adversely impact applications in terms of latency (slowness) and availability. This applies to Live Volumes built on top of synchronous replications as well. For this reason, appropriate performance sizing is paramount for the source and destination storage, as well as the replication bandwidth and any other upstream infrastructure that the storage is dependent on.

Figure 1 demonstrates the write I/O pattern sequence with synchronous replication:

1. The application or server sends a write request to the source volume.
2. The write I/O is mirrored to the destination volume.
3. The mirrored write I/O is committed to the destination volume.
4. The write commit at the destination is acknowledged back to the source.
5. The write I/O is committed to the source volume.
6. Finally, the write acknowledgement is sent to the application or server.

The process is repeated for each write I/O requested by the application or server.

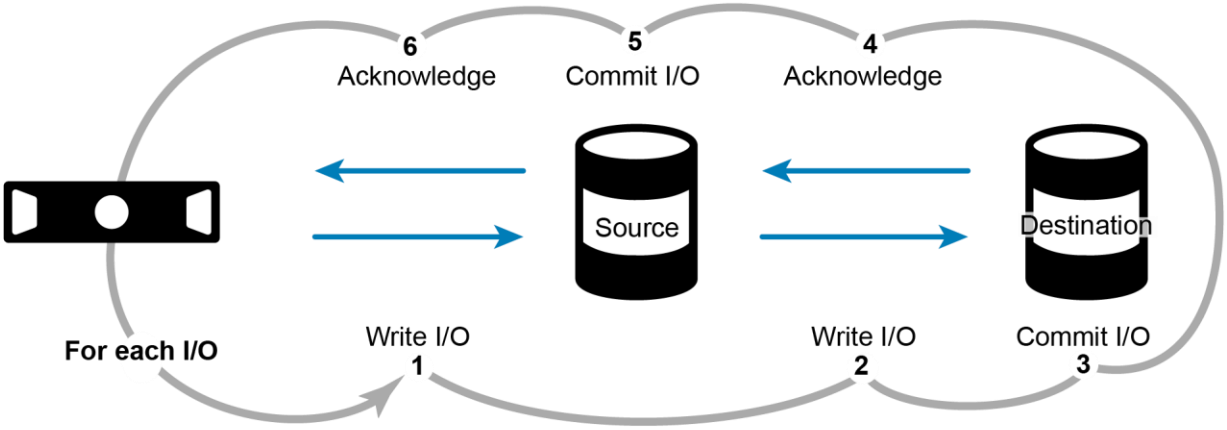


Figure 1 Synchronous replication write I/O sequence

2.1.2 Asynchronous

Asynchronous replication accomplishes the same data protection goal in that data is replicated from source storage to destination storage. However, the manner and frequency that the data is replicated differs from synchronous replication. Instead of committing a write at both replication source and destination simultaneously, the write is committed only at the source and an acknowledgement is then sent to the storage host and application. The accumulation of committed writes at the source volume are replicated to the destination volume in one batch at scheduled intervals and committed to the destination volume.

Aside from replicating the active snapshot (semi-synchronous replication is discussed in section 2.1.3), Asynchronous replication in SC Series storage is tied to the source volume replication schedule. When a snapshot is created on the source volume, and that volume is configured for asynchronous replication, the new snapshot is replicated to the destination volume. Snapshots on a volume may be created automatically according to a schedule or manually created from a variety of integration tools. Regardless, all snapshots occur on a per-volume basis. As a result, volumes may adhere to their own independent replication schedule, or they may share a replication schedule with other volumes leveraging the same snapshot profile. This type of replication is also referred to as a point-in-time replication, which is a type of asynchronous replication that specifically leverages volume snapshots. Because asynchronously replicated transactions are not required to wait for write committals at the replica destination volume, the replication link and/or destination storage will not contribute to application or transaction latency at the source volume.

Figure 2 demonstrates the write I/O pattern sequence with respect to asynchronous replication.

1. The application or server sends a write request to the source volume.
2. The write I/O is committed to the source volume.
3. Finally, the write acknowledgement is sent to the application or server.

The process is repeated for each write I/O requested by the application or server.

4. Periodically, a batch of write I/Os that have already been committed to the source volume are transferred to the destination volume.
5. The write I/Os are committed to the destination volume.
6. A batch acknowledgement is sent to the source.

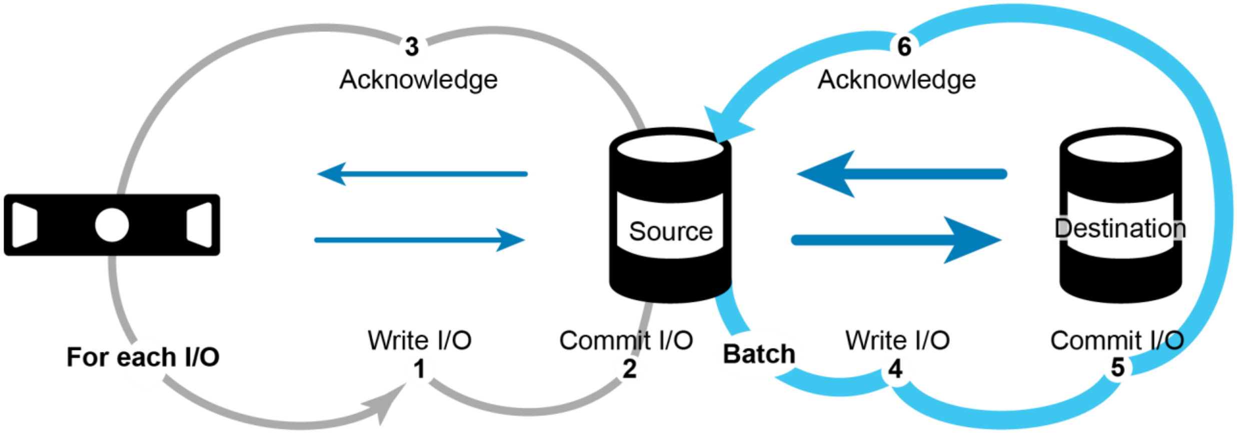


Figure 2 Asynchronous replication write I/O sequence

2.1.3 Semi-synchronous

With SC Series storage, semi-synchronous replication behaves like synchronous replication in that application transactions are immediately sent to the replication destination storage (assuming that the replication link and destination storage have the bandwidth to support the current rate of change). The difference is that the write I/O is committed at the source volume and an acknowledgement is sent to the storage host and application without a guarantee that the write I/O was committed at the destination storage. Semi-synchronous replication is configured in Dell Storage Manager by creating asynchronous replication between two volumes and checking the box for **Replicate Active Snapshot**. A snapshot is an SC Series storage term that describes frozen data. The Active Snapshot refers to newly written or updated data that has not yet been frozen in a snapshot. Semi-synchronous offers a synchronous-like recovery point objective (RPO) without application latency, but the RPO and loss of data in an unplanned outage scenario cannot be guaranteed.

Figure 3 demonstrates the write I/O pattern sequence with semi-synchronous replication.

1. The application or server sends a write request to the source volume.
2. The write I/O is committed to the source volume.
3. The write acknowledgement is sent to the application or server.

The process is repeated for each write I/O requested by the application or server.

For each write I/O that completes that process, there is an independent and parallel process:

a. The write request is sent to the destination.
b. The write I/O is committed to the destination.
c. The write acknowledgement of the mirror copy is sent to the source array.

The commits at the source and destination volumes are not guaranteed to be in lockstep with each other.

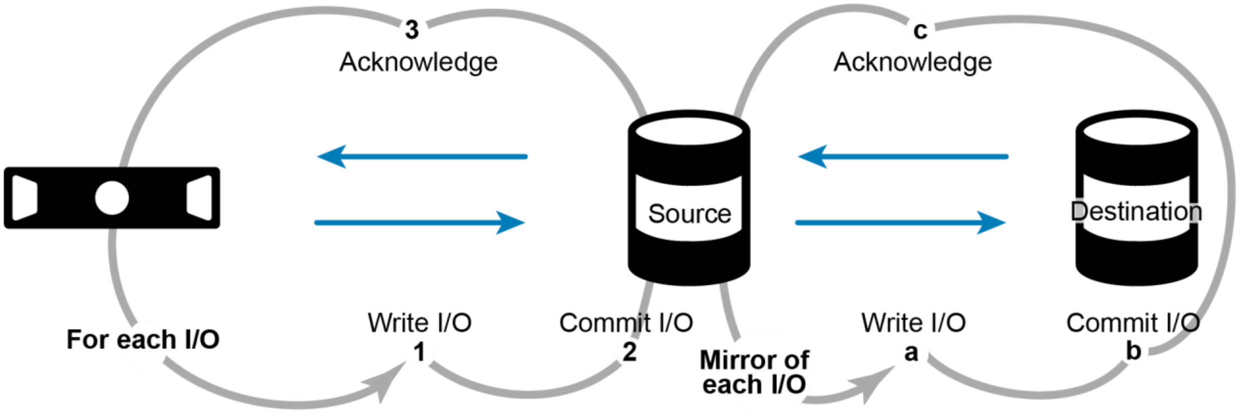


Figure 3 Semi-synchronous replication write I/O sequence

3 Synchronous replication features

SC Series storage supports a wide variety of replication features. Each feature is outlined in the following sections.

3.1 Modes of operation

A number of evolutionary improvements have been made to enhance synchronous replication with SC Series arrays. Among these improvements are choice in replication mode on a per-volume basis. Synchronous replication can be configured in one of two modes: high consistency or high availability.

3.1.1 Legacy

Synchronous replications created prior to SCOS 6.3 are identified as legacy after upgrading to SCOS 6.3 and newer. Legacy synchronous replications cannot be created in SCOS 6.3 or newer and do not possess the newer synchronous replication features currently available. To upgrade a legacy synchronous replication to synchronous high consistency or synchronous high availability replication, a legacy synchronous replication must be deleted and recreated after both source and destination SC Series arrays have SCOS 6.3 or newer installed. Deleting and recreating a synchronous replication will result in data inconsistency between the replication source and destination volumes until 100% of the initial and journaled replication is completed.

3.1.2 High consistency

Synchronous high consistency mode rigidly follows the storage industry specification of synchronous replication outlined earlier and shown in Figure 1. The mechanisms involved with this method of replication will guarantee data consistency between the replication source and destination volumes unless an administrator pauses the replication for maintenance or other reasons. Latency can impact applications at the source volume if the replication link or replication destination volume is unable to absorb the amount of data being replicated or the rate of change. Furthermore, if write transaction data cannot be committed to the destination volume, the write will not be committed on the source volume and in effect, a transaction involving a write fails. An accumulation of write failures will likely result in an application failure or outage when a tolerance threshold is crossed. For these reasons, application latency and high availability are important points to consider in a storage design proposing synchronous replication in high consistency mode.

3.1.3 High availability

Synchronous high availability mode bends the rules of synchronous replication by relaxing the requirements associated with high consistency mode. While the replication link and the replica destination storage are able to absorb the write throughput, high availability mode performs like high consistency mode (described in section 3.1.2 and illustrated in Figure 1). Data is consistently committed at both source and destination volumes and excess latency in the replication link or destination volume will be observed as application latency at the source volume.

The difference between high consistency and high availability mode is that data availability will not be sacrificed for data consistency. What this means is that if the replication link or the destination storage either becomes unavailable or exceeds a latency threshold, the SC Series array will automatically remove the dual write committal requirement at the destination volume. This allows application write transactions at the source volume to continue, with no downstream latency impacts, instead of write I/O being halted or slowed, which is the case with high consistency mode and legacy synchronous replication. This relaxed state is referred to as being **out of date**. If and when an SC Series array enters the out-of-date state, inconsistent write I/O will be journaled at the source volume. When the destination volume becomes available within a tolerable latency threshold, journaled I/O at the source volume is flushed to the destination volume where it will be committed. During this process, incoming application writes continue to be written to the journal. After all journaled data is committed to the destination volume, the source and destination will be in sync and the data on both volumes will be consistent. When the source and destination volumes are in sync, downstream latency will return within the application at the source volume. Similar to the high consistency mode, application latency and data consistency are important points to consider in a design that incorporates synchronous replication in high availability mode.

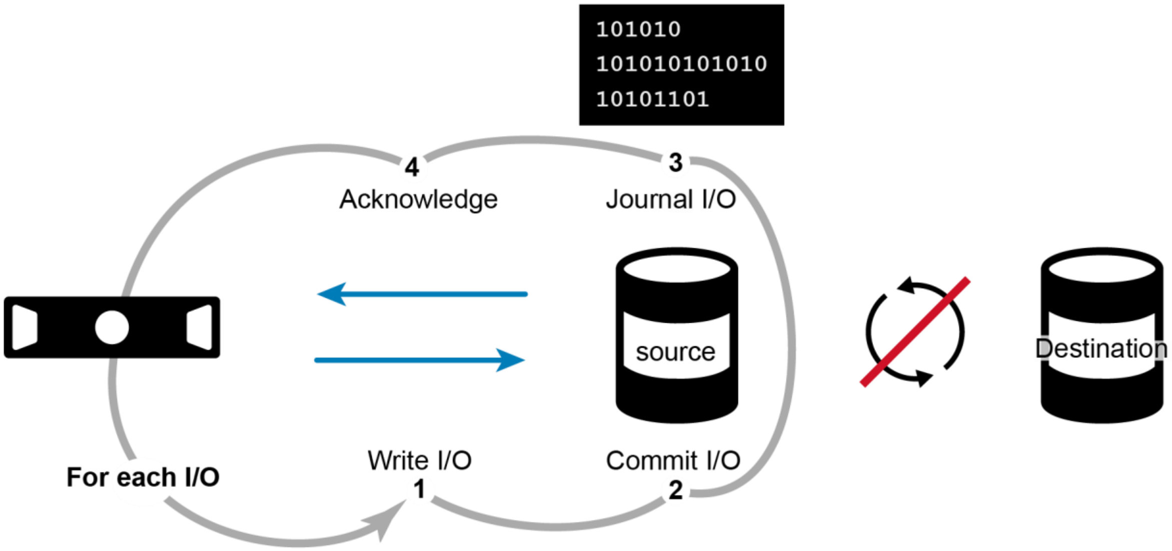


Figure 4 High availability mode synchronous replication in an out-of-date state

3.1.4 Mode migration

In SCOS 6.5 or newer, replications may be migrated from one mode to another without manually having to destroy the replication and destination replica volumes, and then rebuild. This includes migrations such as asynchronous to synchronous high consistency, synchronous high consistency to synchronous high availability, or synchronous high availability to asynchronous. Leveraging the mode migration feature can save significant time and replication bandwidth. It also reduces the data availability risk exposure associated with the time taken to destroy and rebuild a replica volume. Lastly, this method preserves predefined DR settings in Dell Storage Manager that are tied to restore points and replica volumes. For all of these reasons, individually or combined, it is recommended to take full advantage of this feature.

Note: This feature is compatible with all replication modes except legacy synchronous replication.

3.2 Minimal recopy

As discussed in section 3.1.3, synchronous replications configured in high availability mode allow write access to the source volume if the destination volume becomes unavailable or falls behind. While out of date, a journalizing mechanism shown in Figure 4 tracks the write I/O that makes the source and destination volumes inconsistent. Prior to SCOS 6.3 with legacy replication, journaling was not performed and if the destination volume became unavailable and then later available, all data on the source volume needed to be re-replicated to the destination to get back in sync. However, with the minimal recopy feature, only the changed data contained in the journal is replicated to the destination volume in order to bring the source and destination volumes back in sync. This dramatically reduces the recovery time and data inconsistency risk exposure as well as the replication link bandwidth consumed to recover. Minimal recopy is also employed in high consistency mode should the destination volume become unavailable during initial synchronization or an administrator invoked a pause operation on the replication.

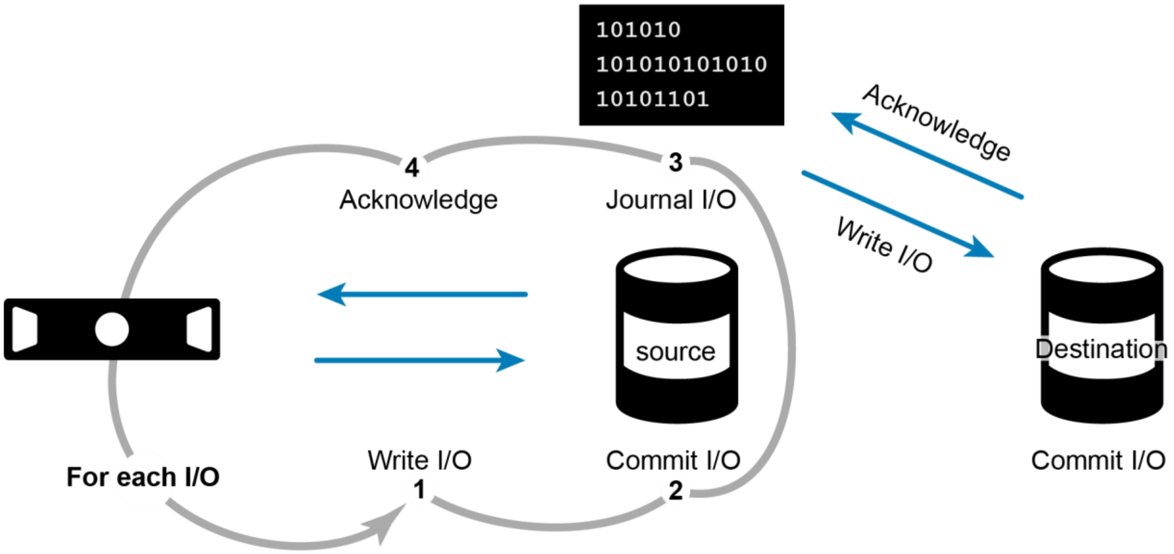


Figure 5 Flushing journaled writes to the destination volume to regain volume consistency

3.3 Asynchronous replication capabilities

Synchronous replication has seen numerous improvements over time and includes key features that were previously associated only with asynchronous replication.

3.3.1 Snapshots and consistency groups

The most notable asynchronous feature is the replication of SC Series snapshots. In the past, only the active snapshot data was replicated from source to destination. With snapshots automatically replicated to the destination site, customers have more flexibility in recovery options with many historical restore points to choose from. By virtue of having snapshot functionality, synchronous replication can be integrated with consistency groups and Replay-Manager-created snapshots across volumes to enable snapshot interval consistency across replicated volumes. In high consistency mode, snapshot consistency will be guaranteed. In high availability mode, snapshot consistency is highly likely.

Note: Consistent snapshots may be created for asynchronous and synchronous replications. However, consistent snapshots are not supported with Live Volumes.

3.3.2 Pause

Synchronous replications configured in either high consistency or high availability modes can be paused without impacting availability of applications relying on the replication source volume. Pausing replication can facilitate multiple purposes. For example, it can be used to relieve replication link bandwidth utilization. In designs where replication bandwidth is shared, other processes can temporarily be given burstable priority. Pausing may also be preferred in anticipation of a scheduled replication link or fabric outage.

3.4 Multiple replication topologies

Dell extends synchronous replication support beyond just a pair of SC Series volumes residing in the same or different sites. A choice of two topologies or a hybrid combination of both is available.

3.4.1 Mixed topology

The mixed topology, also known as 1-to-N (N=2 as of SCOS 6.5), allows a source volume to be replicated to two destination volumes where one replication is synchronous or asynchronous and the additional replications are asynchronous. The maximum number of additional replications is set by the value of N. This topology is useful when data must be protected in multiple locations. If data recovery becomes necessary, a flexible choice of locations is available for recovery.

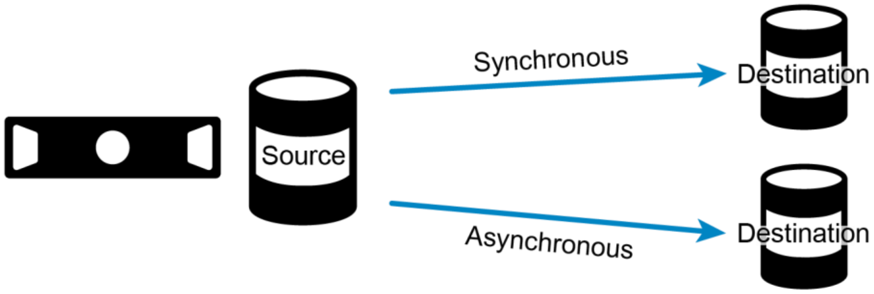


Figure 6 Mixed topology

If the volume replication source becomes unavailable, volume replication stops.

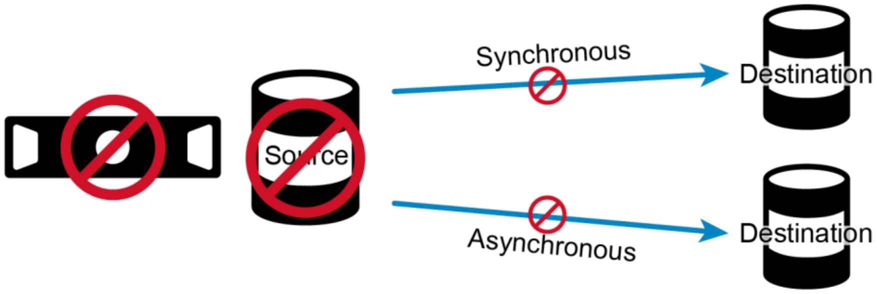


Figure 7 The source volume of a replication becomes unavailable and replication stops

For recovery purposes, the replica can be activated and mapped by Dell Storage Manager to a storage host (for instance, at a disaster recovery site).

Furthermore, in a mixed topology, a replica volume may be configured to replicate to another one of the replicas (asynchronous or synchronous) without having to reseed a majority of the data both volumes would already have before the original source volume became unavailable. This may be useful where two or more disaster recovery sites exist.

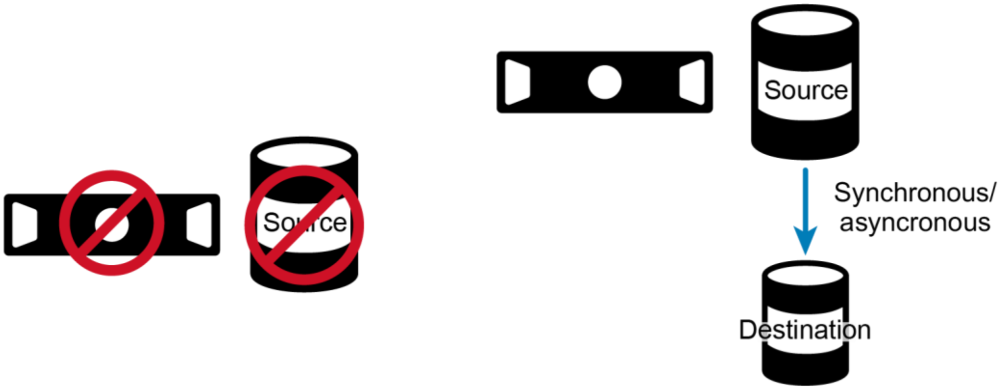


Figure 8 After DR activation, a replica volume can be replicated to another replica with efficiency

3.4.2 Cascade topology

The cascade topology allows asynchronous replications to be chained to synchronous or asynchronous replication destination volumes. This topology is useful in providing immediate reprotection for a recovery site. Similar to the mixed topology, it provides a flexible choice of locations for data recovery or business continuation practices. It could also be used as a means of providing replicas of data in the same data center or a remote site. Copies of Microsoft® SQL Server® or Oracle® databases for parallel test, development, or QA environments are popular examples of this.

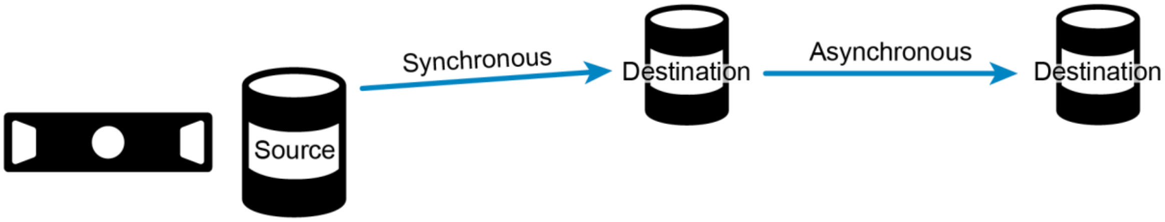


Figure 9 Cascade topology

3.4.3 Hybrid topology

A hybrid topology can also be created by combining mixed and cascade topology types. This configuration is adaptable to virtually any replica or data protection needs a business may require.

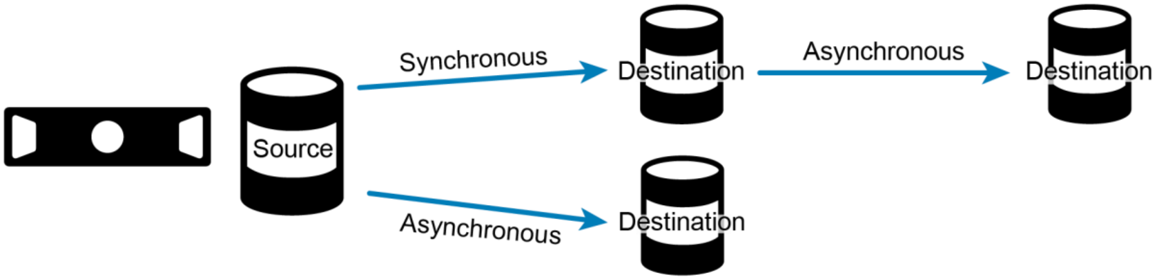


Figure 10 Hybrid topology

3.5 Live Volume

The Live Volume feature, which is discussed in detail later in this document, is built on replication. In versions of SCOS prior to 6.5, Live Volume was supported only with asynchronous replication. With SCOS 6.5 and newer, Live Volume is designed to work in conjunction with asynchronous and synchronous replication types. In addition, Live Volume supports many of the current synchronous replication features such as modes of operation and mode migration.

3.5.1 Preserve Live Volume

In SCOS 6.5 or newer, recovering data from a secondary Live Volume, when the primary Live Volume is unavailable, is faster, easier, and more flexible. Secondary Live Volumes may be promoted to the primary Live Volume role that preserves volume identity and storage host mappings. Alternatively, data on a secondary Live Volume may be recovered by creating a new a View Volume and then mapping that View Volume to one or more storage hosts.

3.5.2 Live Volume automatic failover

SCOS 6.7 introduced automatic failover for Live Volumes. Depending on the nature of the unplanned outage, the recovery process is similar to the Preserve Live Volume feature except that it is completely automated and occurs within a matter of seconds, and at scale.

3.5.3 Live Volume automatic restore

When an unplanned outage occurs, Live Volume automatic failover provides high availability for configured volumes. However, at this point, volume availability is at risk should a second unplanned event impact the remaining system. If the original outage is minimal in scope and the site can be brought back online, the Live Volume automatic restore feature repairs the Live Volume back to a redundant state with no administrator intervention required. Note that a Live Volume role swap does not occur as part of this process meaning a Secondary Live Volume which was recovered as a Primary Live Volume during automatic failover will remain a Primary Live Volume after the automatic restore.

3.5.4 Live Volume managed replication

A Live Volume managed replication is an additional replication and replica volume that uses the primary Live Volume as its replication source. The Live Volume managed replication may be synchronous or asynchronous depending on the Live Volume configuration. To maintain data integrity and consistency, when a Live Volume swap role or failover occurs, the Live Volume managed replication persistently follows the primary Live Volume as its source of replication.

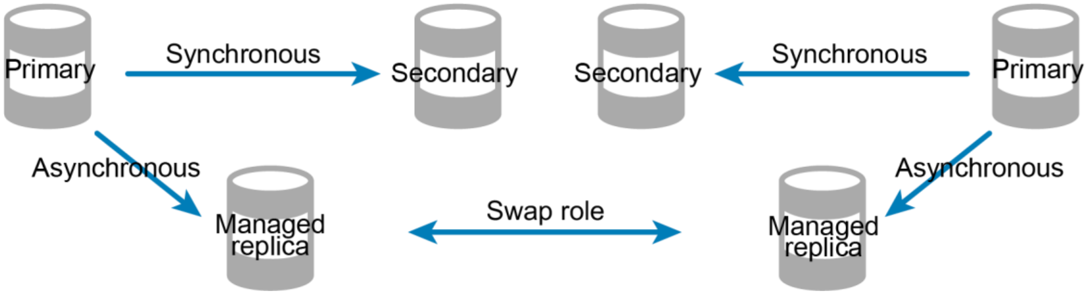


Figure 11 Live Volume managed replication before and after swap role or failover

3.6 Dell Storage Manager recommendations

Dell Storage Manager periodically checks the status of replication and records the progress of completeness. In the event of a failure at the source site, DSM provides a safe recommendation on the use of the destination replica. When using high consistency synchronous replication, data between source and destination must be consistent for DSM to advise it is safe to use the destination replica for recovery.

When using high availability synchronous replication (or high consistency with the ability to pause replication), the data between source and destination volumes may or may not be consistent depending on whether the replication was in sync or out of date at the time of the failure. If at the time of failure replication was in sync, DSM will advise that the destination replica volume is data consistent and safe to use for recovery. Conversely, if the synchronous replication was out of date, this means journaled transactions at the source volume likely have not been replicated to the destination and the destination replica is not data consistent and not recommend for use. At this point, the data recovery options would be to use a data consistent snapshot as the recovery point or continue with using the inconsistent replica. In either case, the most recent transactions will have been lost at the destination but recovering from a snapshot will provide a precise point in time as the recovery point.

3.7 Dell Storage Manager DR recovery

Synchronous replication volumes are supported in the scope of the DSM predefined disaster recovery and DR activation features. Those that have used this feature with asynchronously replicated volumes in the past can extend the same disaster recovery test and execution processes to synchronously replicated volumes. DSM and its core functionality is freely available to SC Series customers, making it an attractive and affordable tool for improving recovery time objectives. Note that DR settings cannot be predefined for Live Volumes, nor can Live Volume restore points be test activated.

3.8 Support for VMware vSphere Site Recovery Manager

Standard asynchronous or synchronous (either mode) replication types can be leveraged by VMware® vSphere® Site Recovery Manager (SRM) protection groups, recovery plans, and reprotection.

SRM version 6.1 support for stretched storage with Live Volume was added in DSM 2016 R1. Supported deployment configurations are outlined in the document, Dell EMC SC Series Best Practices with VMware Site Recovery Manager. For more information on use cases and integrating stretched storage with SRM, please see the Site Recovery Manager Administration documentation provided by VMware.

4 Synchronous replication use cases

Replicating data can be a valuable and useful tool, but replication by itself serves no purpose without tying it to a use case to meet business goals. The following sections highlight sample use cases for synchronous replication.

4.1 Overview

Array-based replication is typically used to provide upper tier application high availability or disaster recovery, a data protection process to enable image or file-level backup and recovery, or a development tool to generate copies of data in near or remote locations for application development or testing purposes. For many business use cases, asynchronous replication provides a good balance of meeting recovery point objective (RPO) and recovery time objective (RTO) service level agreements without a cost-prohibitive infrastructure such as dark fibre, additional networking hardware, or additional storage. This is why asynchronous replication is often used between data centers where longer distances are involved.

However, there are an increasing number of designs where a strong emphasis is placed on the prevention of data loss. Regardless of where the need originates, the method of replication that satisfies zero transaction loss is synchronous. The next few sections highlight examples of synchronous replication with a focus on high consistency for zero data loss or high availability for relaxed data consistency requirements.

4.2 High consistency

The primary need for synchronous replication is preventing data loss or guaranteeing data consistency between the source and destination replica volume. Synchronous replication provides the same data protection benefits for both proactive and reactive use cases. Refer to section 3 for more detail on synchronous high consistency replication operational characteristics.

4.2.1 VMware and Hyper-V

When virtualized, server workloads in the data center are encapsulated into a small set of files that represent the virtual BIOS, virtual hardware resources, and the virtual disks that provide read and write access to data. The I/O profile is dependent on the virtual machine role and the applications and services running within it. Virtual machines work particularly well with replication because their compute resources are portable and hardware independent by nature. Their inherent mobility, combined with storage replication, allows them to easily migrate from one site to another, with comparatively little effort required to bring them online at the destination site. Virtual machines may be relocated for load balancing or disaster avoidance/recovery purposes. Whatever the reason for relocation, high consistency synchronous replication will ensure that the contents of the virtual machine at the source and destination match. In the event the vSphere or Microsoft® Hyper-V® virtual machine needs to be migrated to a host or cluster of hosts at the destination site, data consistency of the virtual machine being brought up at the destination site is guaranteed. Disaster recovery is covered in more detail in section 4.5.

Note that Dell Storage Manager DR plans cannot be predefined with Live Volumes. Predefined DR plans are supported with regular (asynchronous or synchronous) volume replications or with a managed (cascaded or hybrid) asynchronous replication from a Live Volume.

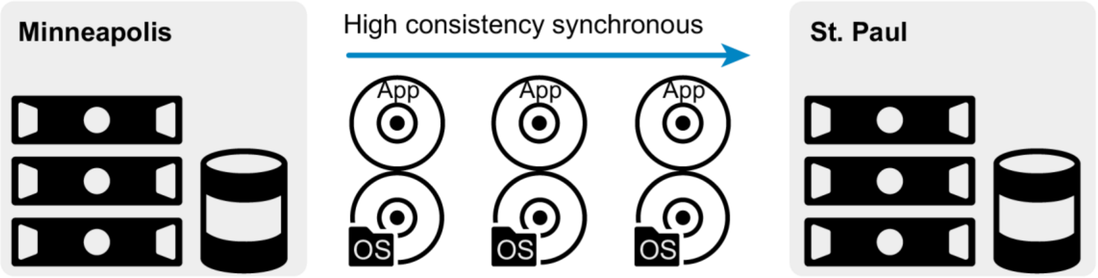


Figure 12 High consistency synchronous with consolidated vSphere or Hyper-V sites

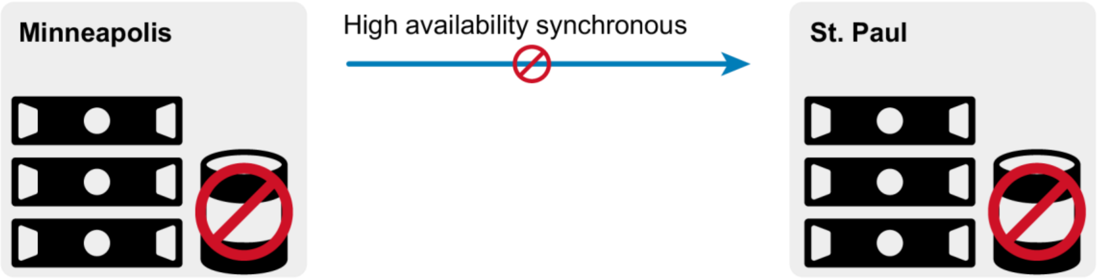


Figure 13 A replication link or destination volume issue in St. Paul results in a VM outage in Minneapolis

4.2.2 Microsoft SQL Server and Oracle Database/Oracle RAC

Database servers and clusters in critical environments are often designed to provide highly available, large throughput, and low latency access to data for application tier servers and sometimes directly to application developers or end users. Database servers differ from virtual machines in that protection of the database volumes is paramount while protection of the operating system is not required for data recovery. However, booting from SAN and replicating that SAN volume to a remote site with compatible hardware can drastically improve RTO. Similar to virtual environments, the critical data may be spread across multiple volumes. When designing for performance, application, or instance isolation, this is often the case. Unless the replication is paused, consistency between volumes is guaranteed in high consistency mode because the write order at the destination will mirror the write order at the source, otherwise the write will not happen in either location (see Figure 15). This is the fundamental premise of high consistency mode detailed in section 3.1.2.

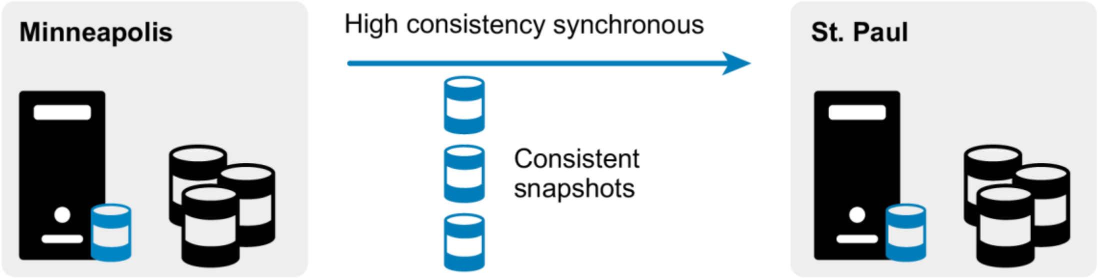


Figure 14 High consistency synchronous with databases

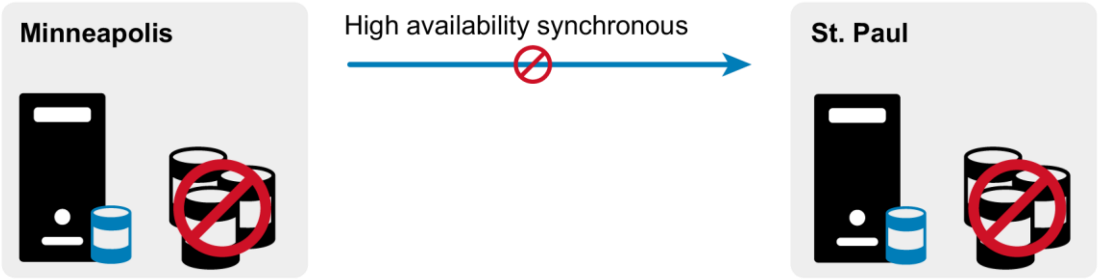


Figure 15 A replication link or destination volume issue in St. Paul results in database outage in Minneapolis

To summarize, there are high consistency use cases that can be integrated with virtualization as well as database platforms. The key benefit being provided is data consistency and zero transaction loss. Keep in mind that the infrastructure supporting synchronous replication between sites must perform sufficiently. In the case of high consistency, the supporting infrastructure must be highly redundant and immune to outages for slowness or an outage of the replication link or the destination site is reflected equally at the source site where the end user applications are running.

An important factor when considering the type of replication to be implemented is that the infrastructure required to keep two sites well connected, particularly at greater distances, often comes at a premium. Stakeholders may be skeptical about implementing a design where a failure at the secondary site or a failure of the connection between sites can have such a large impact on application availability and favor asynchronous replication over synchronous replication. However, with the high availability synchronous replication offered with SC series storage, customers have additional flexibility compared to legacy synchronous replication.

4.3 High availability

Many organizations prefer asynchronous replication for its cost effectiveness and its significant reduction in risk of an application outage, should the destination storage become unavailable. The high availability synchronous replication mode in SC Series arrays provide data consistency throughout normal uptime periods. However, if unexpected circumstances arise resulting in a degradation or outage of the replication link or destination storage, latency or loss of production application connectivity at the replication source is not at risk. While this deviates slightly from the industry-recognized definition of synchronous replication, it adds flexibility that is not found in high consistency synchronous by blending desirable features of both synchronous and asynchronous replication. In addition, SC Series storage automatically adapts to shifting destination replica availability. Refer to section 3 for more detail on high availability synchronous replication operational characteristics.

4.3.1 VMware and Hyper-V

Encapsulated virtual machines are replicated in a data consistent manner as they are when using high consistency mode replication. The difference of behavior comes into play if the replication link (or the destination replica volume) becomes burdened with excess latency or is unavailable. Instead of failing writes from the hypervisor, the writes are committed and journaled at the source volume, allowing applications to continue functioning but at the expense of a temporary lack of data consistency while the destination volume is unavailable.

In the following examples, note that using high availability mode in place of high consistency mode does not automatically allow the design to be stretched over further distances without consideration to application latency. High availability mode is still a form of synchronous replication and should not be confused with asynchronous replication. Adding significant distance between sites generally results in latency increases which will still be observed in the applications at the source side for as long as the high availability replication is in sync.

Finally, if virtual machines are deployed in a configuration that spans multiple volumes, consider using Replay Manager or consistency groups. Replay Manager is covered in section 11.6.

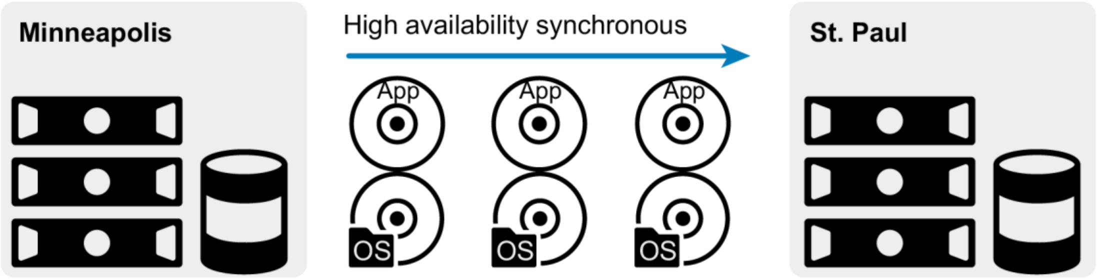


Figure 16 High availability synchronous with consolidated vSphere or Hyper-V sites

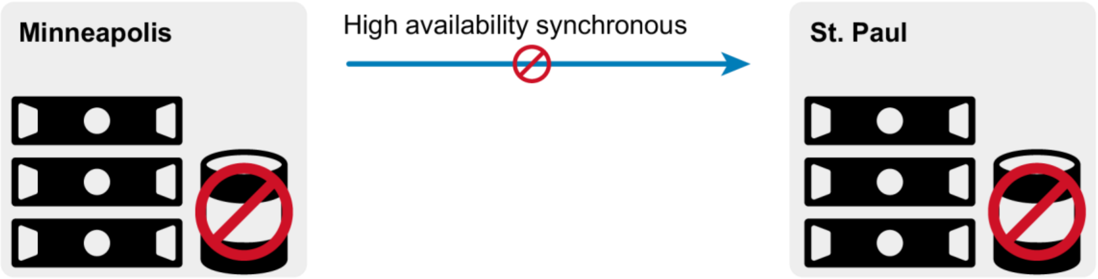


Figure 17 A replication link or destination volume issue in St. Paul results in no VM outage in Minneapolis

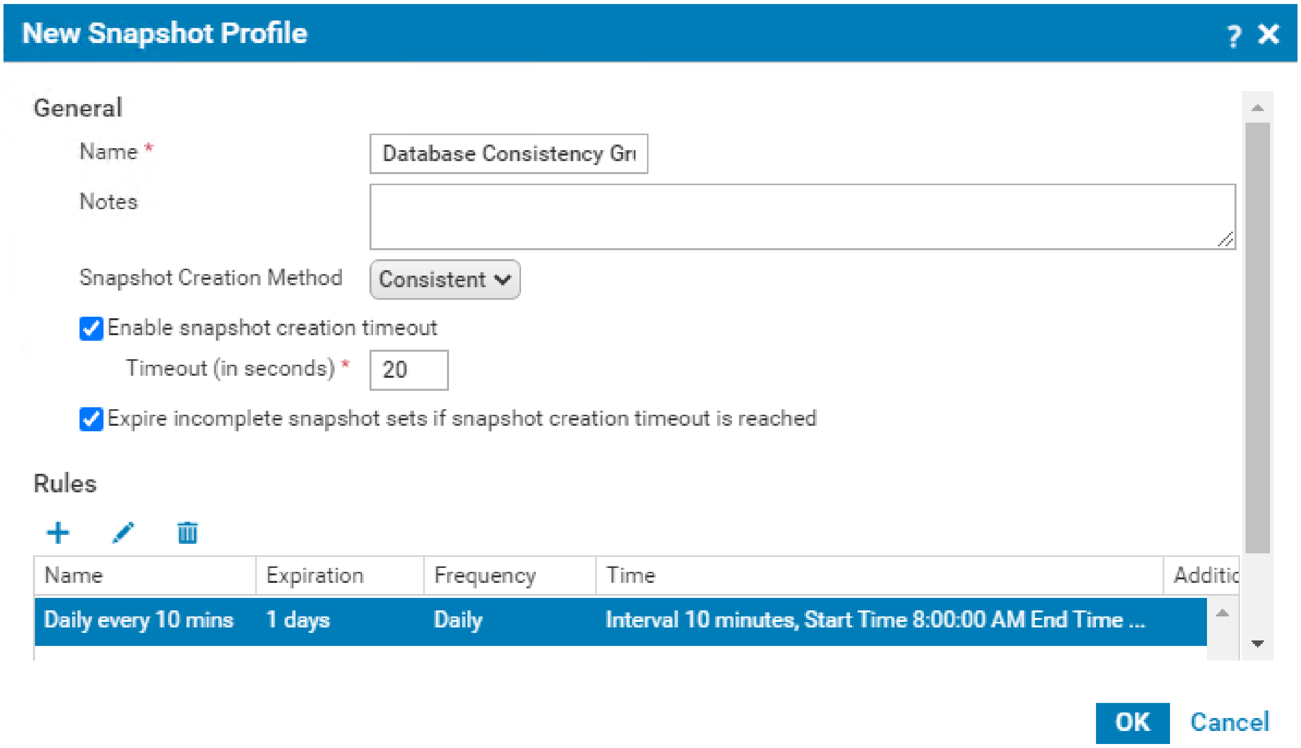
Note: Consistent snapshots may be created for asynchronous and synchronous replications. However, Consistent snapshots are not supported with Live Volumes.

4.3.2 Microsoft SQL Server and Oracle Database/Oracle RAC

As discussed in section 4.3.1, the behavioral delta between high availability and high consistency modes is minimal until extreme latency or an outage impacts the destination volume availability. If high availability synchronous replication falls into an out-of-date state, write I/O at the source volume is journaled and the destination volume becomes inconsistent. In terms of recovery, this may or may not be acceptable. A feature in Dell Storage Manager advises customers on whether or not the active snapshot on the destination volume is safe to recover from at a data consistency level. In the event that DSM detects the data is not consistent, the recommendation is to revert to the most recent consistent snapshot associated with the destination volume (another new feature in synchronous replication: replication of snapshots).

For storage hosts with data confined to a single volume, special considerations are not necessary. However, if the host has application data spread across multiple volumes (for example, a VM with multiple virtual machine disk files, or a database server with instance or performance isolation of data, logs, and other files) then it becomes critical to ensure snapshot consistency for the replicated data that will be used as a restore point. Ensuring all volumes of a dataset are quiesced and then snapped at precisely 8:00, for example, provides a data consistent restore point across volumes supporting the dataset. This snapshot consistency is accomplished with Replay Manager (especially recommended for Microsoft products through VSS integration) or by containerizing volumes by use of consistency groups.

To create consistency across snapshots using consistency groups, a snapshot profile is created with a snapshot Creation Method of Consistent (Figure 18). This profile is then applied to all volumes containing the dataset. For virtual machines, the volumes would contain the virtual disks representing the c: drive, d: drive, or Linux mount points such as / or /tmp. For Microsoft SQL Server database servers, the volumes may represent system databases, application databases, transaction logs, and tempdb. For Oracle databases, the dataset must contain all volumes containing any part of the database (data, index, data dictionary, temporary files, control files, online redo logs, and optionally offline redo logs). For Oracle RAC, OCR files or voting disks can be added to the dataset. For either database platform, separate volumes for hot dumps, archived redo logs, or boot from SAN may exist but typically would not need to be included in a consistency group with the key database files.


New Snapshot Profile

General

Name * Database Consistency Gr

Notes

Snapshot Creation Method Consistent

☑ Enable snapshot creation timeout

Timeout (in seconds) * 20

☑ Expire incomplete snapshot sets if snapshot creation timeout is reached

Rules

Name	Expiration	Frequency	Time	Additic
Daily every 10 mins	1 days	Daily	Interval 10 minutes, Start Time 8:00:00 AM End Time ...	

Figure 18 Creating a consistency group in Unisphere Central for SC Series

Note: Consistent snapshots may be created for asynchronous and synchronous replications. However, consistent snapshots are not supported with Live Volumes.

Another method of capturing consistency in snapshots across volumes (and perhaps more useful for customers with Microsoft Windows, SQL Server, Exchange, Hyper-V, or VMware vSphere) would be to use Replay Manager. Replay Manager has the underlying storage integration and VSS awareness required to create application consistent snapshots, across volumes if necessary, which can then be replicated synchronously (either mode) or asynchronously.

Once data is frozen with consistency across volumes using Replay Manager or consistency groups, those snapshots will be replicated to the destination volume where they can serve as historical restore points for high availability mode recovery, disaster recovery, or remote replicas which will be discussed in the coming sections.

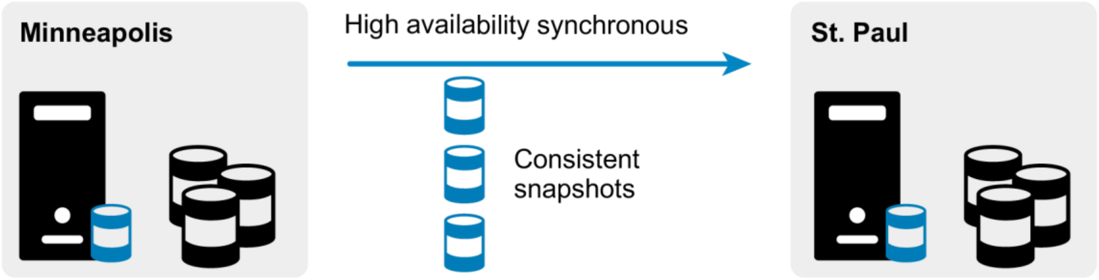


Figure 19 High availability synchronous with databases

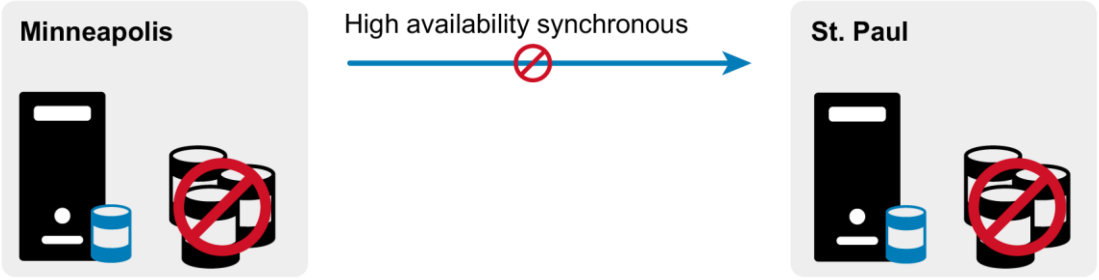


Figure 20 A replication link or destination volume issue in St. Paul results in no database outage in Minneapolis

4.4 Remote database replicas

One practice commonly found in organizations with Microsoft SQL Server or Oracle database technologies is to create copies of databases. There are several reasons to clone databases, and most of them stem from the common principle of minimal or no disruption to the production database, and thus to the application and end users. To identify a few examples, at least one separate copy of a database is maintained for application developers to develop and test code against. A separate database copy is maintained for DBA staff to test index changes, queries, and for troubleshooting areas such as performance. A copy of the production database may be maintained for I/O intensive queries or reporting. SC Series storage snapshots and View Volumes are a natural tactical fit for fulfilling database replica needs locally on the same SC Series array.

However, if the replica is to be stored on a different array, whether or not it is in the same building or geographic region, replication or portable volume must be used to seed the data remotely, and replication should be used to refresh the data as needed. For the purposes of developer or DBA testing, asynchronous replication may be timely enough. However, for reporting purposes, synchronous replication will ensure the data is up to date when the reporting database is refreshed using the replicated volumes. The choice of providing zero data loss through high consistency mode or a more flexible high availability mode should be decided ahead of time with the impacts of each mode well understood.

SC Series snapshots, as well as asynchronous and synchronous replication, are natively space and bandwidth efficient on storage and replication links respectively. Only the changed data is frozen in a snapshot and replicated to remote SC Series arrays. In the following figure, notice the use of high availability synchronous replication within the Minneapolis data center. Although the two arrays are well connected, the risk of internal reporting database inconsistency does not warrant a production outage for the organization.

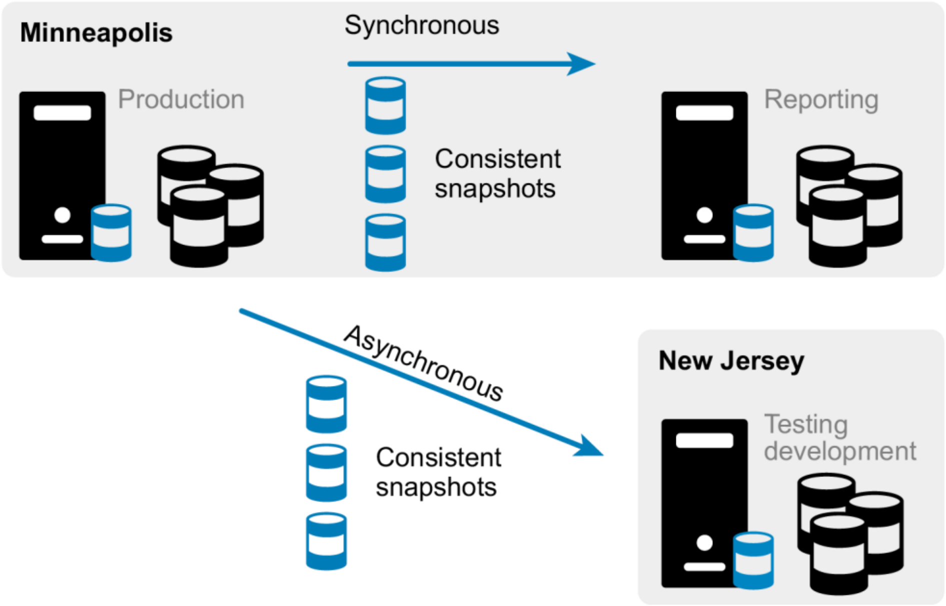


Figure 21 Database replicas distributed in a mixed topology

4.5 Disaster recovery

With data footprints growing exponentially, backup and maintenance windows shrinking along with the cost of storage, and the impact of downtime gnawing on the conscience of businesses, migrating to online storage-based data protection strategies is trending for a variety of organizations. Legacy processes which dumped data to tape were once cost effective and acceptable, but the convergence of key decision-making factors has prompted a shift from yesterday's nearline storage to the more affordable and efficient online storage of today. Data replication within or between sites is the ubiquitous backbone for much more scalable data protection strategies. With replication in place as the data mover, an assortment of vendor and platform provided tools and methods can be coupled to replication to form a manual or electronically documented and reliable recovery process. The SC Series support for multiple replication topologies really comes into play in the disaster recovery conversation because it adds a lot of flexibility for customers wanting to provide data protection for multiple or distributed site architectures. Before getting into platform-specific examples, two fundamental disaster recovery metrics need to be understood as they will be referenced throughout business continuation planning discussions.

Recovery point objective (RPO): This is the acceptable amount of data loss measured by time or the previous point in time at which data is recovered from. An RPO is negotiated with business units and predefined in a disaster recovery plan. In terms of replication, the keys to achieving an RPO target are choosing the appropriate replication type, making sure replication is current (as opposed to out of date or behind), and knowing the tools and processes required to recovery from a given restore point.

Recovery time objective (RTO): This is the elapsed recovery time allowed to bring up a working production environment. Just like RPO, RTO is negotiated with business units and predefined in a disaster recovery plan and may also be included in a service level agreement (SLA). The keys to achieving targeted RTO may vary from data center to data center but they all revolve around process efficiency and automation tools wherever possible. Replication is a quintessential contributor to meeting RTO, especially at large scale.

By leveraging replication, aggressive RPOs and RTOs can be targeted. Data footprint and rate of change growth may be continuous, but feasible RPO and RTO goals do not linearly diminish as long as the replication infrastructure (this includes network, fabric, and storage) can scale to support the amount of data being replicated and the rate of change.

4.5.1 Hyper-V and VMware

As discussed in previous sections, replicating the file objects that form the construct of a virtual machine takes advantage of the intrinsic encapsulation and portability attributes of a VM. Along with hardware independence, these attributes essentially mean the VM can be moved to any location where a supported hypervisor exists, and a VM or group of VMs are quickly and easily registered and powered on depending on the hypervisor and the automation tools used to perform the cutover. Compare this to legacy methods of disaster recovery in which physical or virtual servers are built from the ground up at the recovery site, applications needed to be installed and configured, and then large amounts of data needed to be restored from tape. Instead, at the time a disaster is declared, virtual machines and their configured applications are essentially ready to be added to the hypervisor’s inventory and powered on. Virtualization and replication shave off massive amounts of recovery time, which helps achieve targeted RTO. When the VMs are powered on, their application data payload from the most recently completed replication is already present, meeting the RPO component of the DR plan.

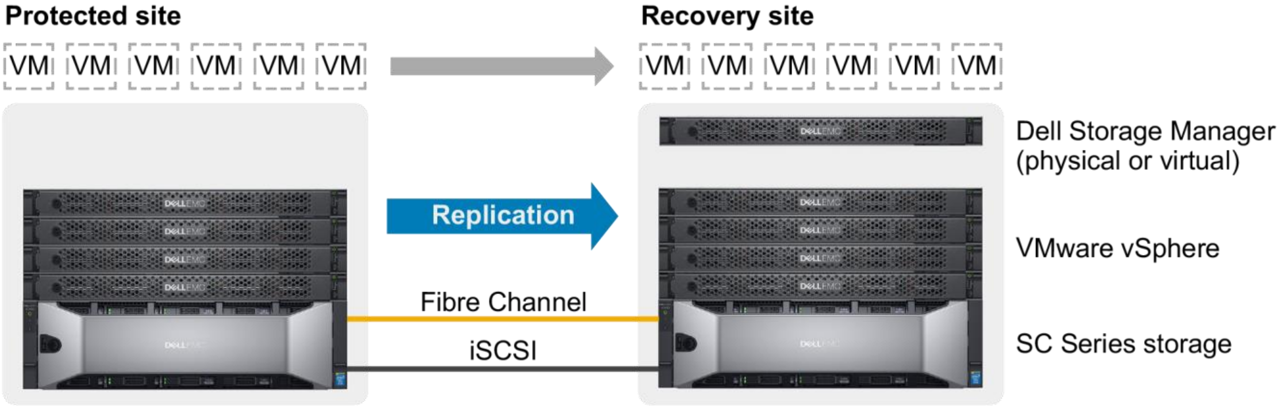


Figure 22 Virtualization and replication combined meet aggressive RTOs and RPOs

4.5.2 Microsoft SQL Server and Oracle Database/Oracle RAC

Aside from infrastructure servers such as Microsoft Active Directory®, LDAP, DNS, WINS, and DHCP, database servers are among the first assets to be recovered. Typically, databases are classified as tier 1 infrastructure (tier 1 assets included in a DR plan receive first recovery priority) and database servers are the first tier that must be brought online in a multi-tier application architecture. The next online is the application tier servers, and then the application front end (on either client desktops or a load-balanced web portal).

RTO is a paramount metric to meet in testing and executing a live business continuation plan. In a DR plan, all steps are predefined and executed in order according to the plan; some steps may be carried out in parallel. Successfully recovered database servers are a required dependency beginning early in the DR plan. This includes bringing up application and web servers that have a critical tie to the database server. The more databases a shared database server hosts, the broader the impact because the number of dependent application and front-end tiers fan out.

Industry analysis reflects data growing at alarming rates across many verticals. Providing performance and capacity is not a challenge with current technology, but protecting the data is. Data growth drives changes in technology and strategy so that SLAs, RTOs, and RPOs can still be maintained even though they were defined when data was a fraction of the size it is today. Restoring 10 TB of data from tape is probably not going to satisfy a 24-hour RTO. Data growth on tapes means that there is a growing number of sequential-access, long-seek time tapes for restoration. This diminishes the chances of meeting RTO, and increases the chances that one bad tape will cause data recovery to fail. Data replication is a major player in meeting RTO.

Intra-volume consistency is extremely important in a distributed virtual machine disk or database volume architecture. Comparing the synchronous replication modes, high consistency guarantees data consistency between sites across all high consistency replicated volumes. Unfortunately, this is at the cost of destination site latency, or worse, downtime of the production application if the destination volume becomes unavailable or exceeds latency thresholds.

Outside of use cases that require the textbook definition of synchronous replication, high availability mode (or asynchronous) may be a lot more attractive for DR purposes. This mode offers data consistency in the proper conditions, as well as some allowance for latency while in sync. However, consistency is not guaranteed if production application uptime is jeopardized should the destination volume become unavailable.

Because consistency cannot be guaranteed in high availability mode, it is important to implement VSS-integrated Replay Manager snapshots or consistency groups with high availability synchronous replication where a multiple volume relationship exists (this is commonly found in both SQL Server and Oracle environments). While this will not guarantee active snapshot consistency across volumes, the next set of frozen snapshots that have been replicated to the remote array should be consistent across volumes.

4.5.3 Preparing and executing volume and data recovery

With the appropriate hypervisor, tools, and automation in the DR plan, powering on a virtual machine is relatively simple. Likewise, preparing the volumes for use and getting the database servers up and running requires a quick process compared to legacy methods. This is especially true when replicating database server boot from SAN (BFS) volumes with similar hardware at the DR site.

When choosing to access volumes at the DR site, it is important to consider the purpose. Is this a validation test of the DR plan, or is this an actual declared disaster? As an active replication destination target (regardless of asynchronous, synchronous, mode, or topology), destination volumes cannot be mounted for read/write use to a storage host at the DR site. (For circumstances involving Live Volume, refer to section 5). To perform a test of the DR plan, present view volumes from the snapshots of each test volume to the storage hosts. Snapshots and view volumes are available for both asynchronous and synchronous replications in either high consistency or high availability mode. Snapshots and view volumes are beneficial during DR testing because replication continues between the source and destination volumes to maintain RPO in case an actual disaster occurs during the test. Conversely, if a disaster is being declared and the Activate Disaster Recovery feature is invoked, then replication from source to destination needs to be halted (if it has not been already by the disaster) if the active volume at the destination site is intended for data recovery in the DR plan.

Unisphere Central for SC Series in Dell Storage Manager is a unified management suite available to SC Series and Dell FS8600 customers. Unisphere Central has disaster recovery features built into it that can create, manage, and monitor replications, as well as automate the testing and execution of a predefined DR plan.

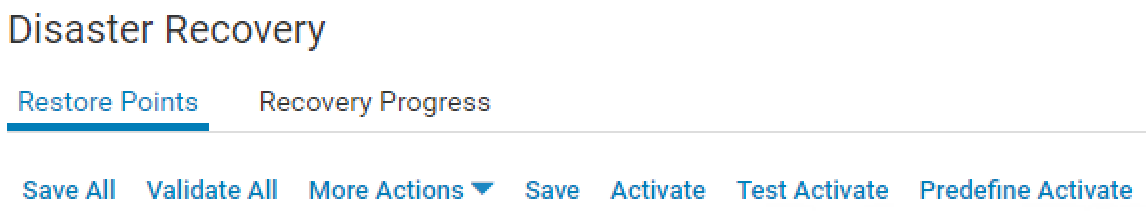
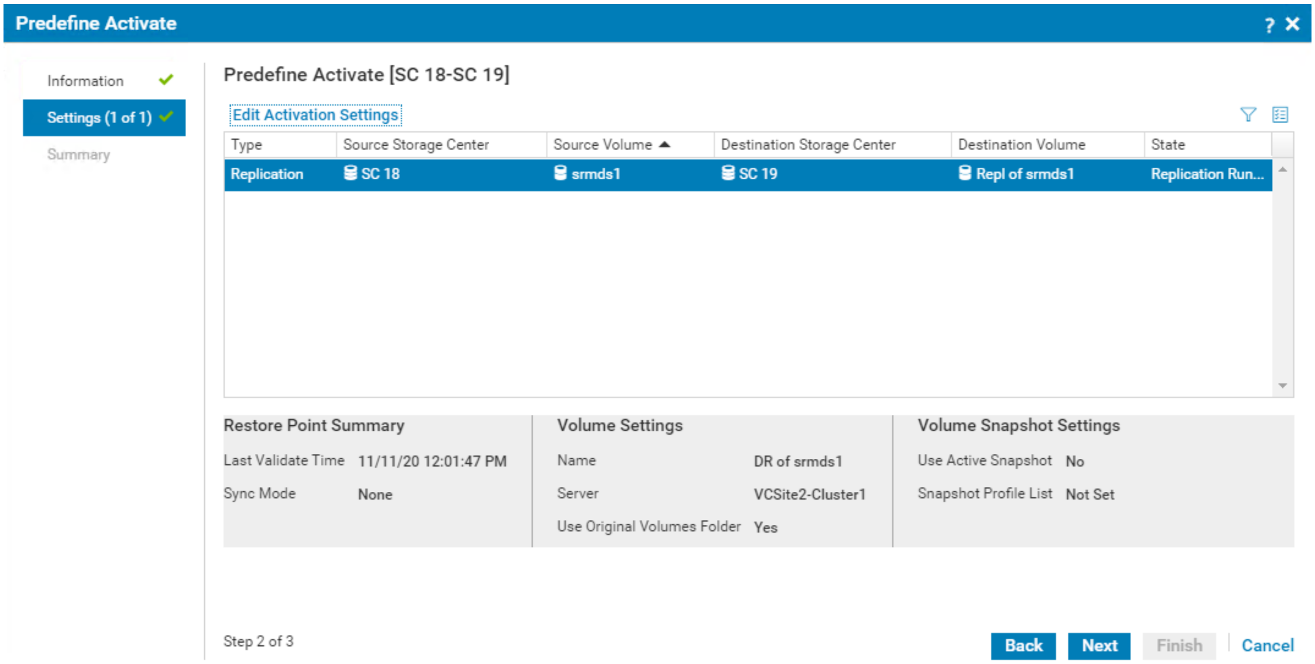


Figure 23 DSM bundles DR automation tools to help meet RTO requirements

For virtualization and database use cases alike, Unisphere Central is used to create asynchronous or synchronous replications. These replications predefine the destination volumes that will be presented to storage hosts for disaster recovery.

Note: Destination replica volumes are for DR purposes only and should not be used actively in a Microsoft or VMware vSphere Metro Storage Cluster design.

In most cases, predefined destination volumes are data volumes. Where physical hosts are involved, boot from SAN volumes can also be included in the pre-defined DR plan to quickly and effortlessly recover physical hosts and applications as opposed to rebuilding and installing applications from scratch. Rebuilding takes significant time, is error prone, and may require subject matter expert knowledge of platforms, applications, and the business depending on how well detailed the build process is in the DR plan. Confusion or errors during test or DR execution lead to high visibility failure. Detailed and current DR documentation provides clarity at the DR site. Process inconsistency and errors are mitigated by automation or closely following DR documentation. With these points in mind, the benefit of automating a DR plan with DSM (or a similar tool) is clear. From the moment a disaster is declared by the business, the RTO is in jeopardy; automation of tasks saves time and provides process consistency.



Predefine Activate [SC 18-SC 19]

Type	Source Storage Center	Source Volume ▲	Destination Storage Center	Destination Volume	State
Replication	SC 18	srmds1	SC 19	Repl of srmds1	Replication Run...

Restore Point Summary

Last Validate Time 11/11/20 12:01:47 PM

Sync Mode None

Volume Settings

Name DR of srmds1

Server VCSite2-Cluster1

Use Original Volumes Folder Yes

Volume Snapshot Settings

Use Active Snapshot No

Snapshot Profile List Not Set

Step 2 of 3

Figure 24 Predefining a DR plan in Unisphere Central for SC Series

Once the volumes are prepared and presented manually or automatically by DSM or API scripting, the process of data recovery continues. For SQL Server and Oracle database servers, databases are attached and various scripts are run to prepare the database server and applications for production use (such as to resync login accounts). For VMware vSphere and Hyper-V hosts, VM datastores are now visible to the hosts and VMs need to be added to the inventory so that they can be allocated as compute and storage resources by the hypervisor and then powered on.

In Hyper-V 2008 R2, the configuration file for each virtual machine must be generated with the correct number of processors, memory, network card, and attached virtual machine disk files. This is a process that is documented or scripted prior to the DR event. Hyper-V 2012/R2 and newer includes a virtual machine import wizard that is able to import the existing virtual machine configuration located on replicated Dell storage, rather than generating a new configuration for each VM from scratch. Once the VMs are added to inventory in Hyper-V 2008 R2 or Hyper-V 2012/R2 and newer, they can be powered on. All versions of VMware vSphere have the same capability as Hyper-V 2012/R2 and newer in that once datastores are presented to the vSphere hosts, the datastores can be browsed and the virtual machine configuration file that is located in each VM folder can be added to inventory and then powered on. A manual DR process, especially in an environment with hundreds or thousands of virtual machines, quickly eats into RTO. The automation of discovering and adding virtual machines to inventory is covered in the next section.

VMware vSphere Site Recovery Manager is a disaster recovery and planned migration tool for virtual machines. It bolts onto an existing vSphere environment and leverages Dell Technologies™ certified storage and array-based replication. Both synchronous and asynchronous replication are supported as well as each of their native features. Live Volume stretched storage is also supported in specific configurations starting with SRM 6.1. With this support, customers can strive for RPOs that are more aggressive and maintain compatibility with third party automation tools, like SRM, to maintain RTOs in large VMware virtualized environments.

For vSphere environments, SRM invokes the commands necessary for tasks (such as managing replication, creating snapshots, creating view volumes, and presenting and removing volumes from vSphere hosts) to be performed at the storage layer without removing DSM from the architecture. The storage-related commands from SRM flow to the Storage Replication Adapter (SRA) and then to the DSM server. For this reason, a DSM Data Collector needs to remain available at the recovery site for the automation to be carried out. Outside of SRM, in a heterogeneous data center, DSM or API scripting would be needed to carry out the DR automation for Hyper-V or physical hosts.

Beyond the scope of storage, SRM automates other processes of DR testing, DR recovery, and planned migrations, making it a major contributor to meeting RTO goals. SRM takes care of important, time-consuming tasks such as adding virtual machines to inventory at the DR site, modifying TCP/IP address configurations, VM dependency, power-on order, and reprotection of virtual machines.

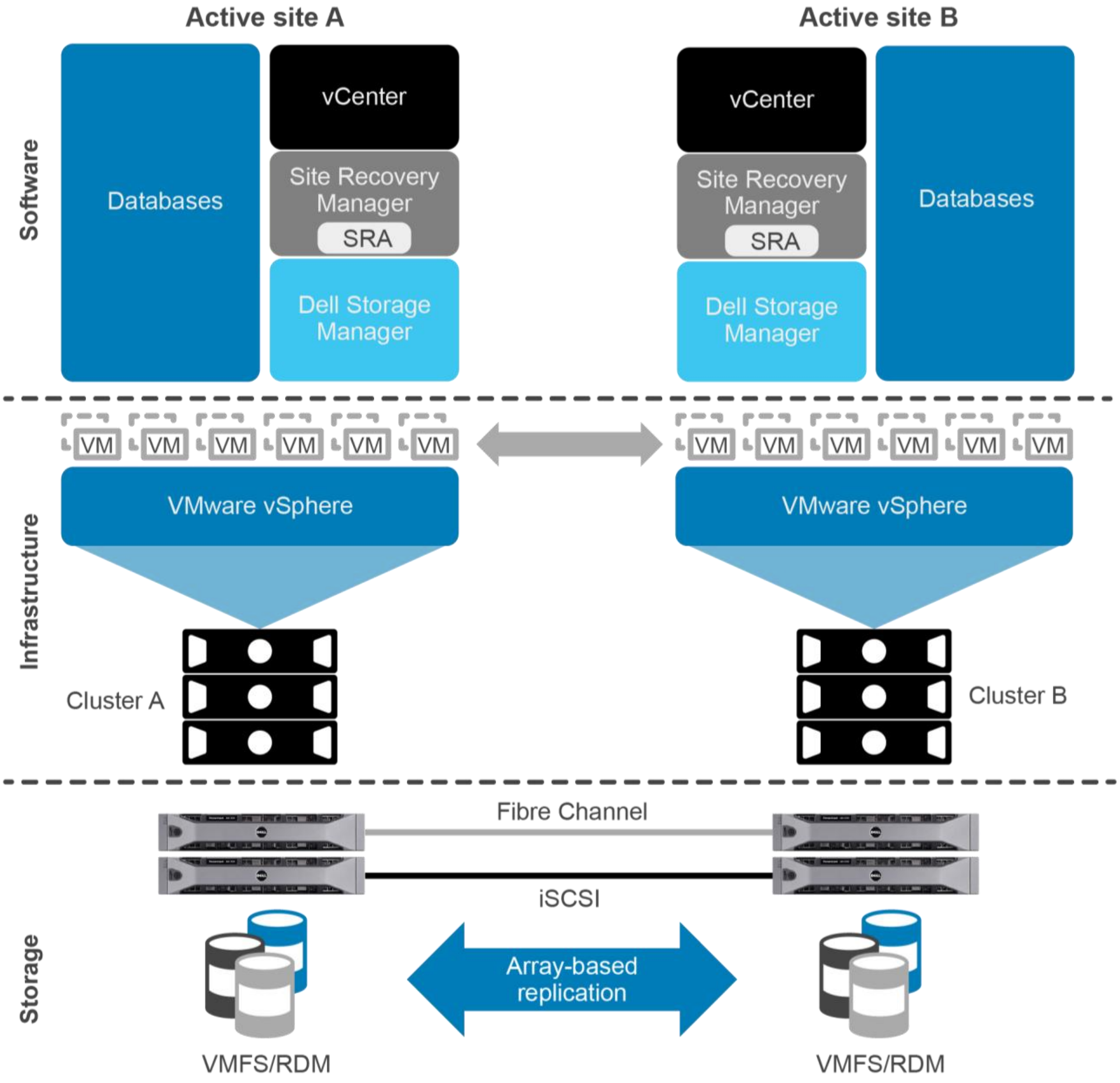


Figure 25 VMware vSphere Site Recovery Manager and SC Series active/active architecture

The DSM server must be available to perform DR testing or an actual DR cutover for an automated DR solution involving SC Series storage replication. This means making sure that at least one DSM server resides at the recovery site so that it can be engaged when needed for DR plan execution. The DSM server labeled as a physical server in Figure 22 also represents a virtualization candidate if it is already powered on and not required to automate the recovery of the vSphere infrastructure where it resides.

4.5.4 Topologies and modes

Replication of data between or within data centers is the fastest, most efficient, and automated method for moving large amounts of data in order to provide replica data, data protection, and business continuation in the event of a disaster. This section provides examples of the different topologies and modes available with synchronous replication in addition to appropriate uses of asynchronous replication.

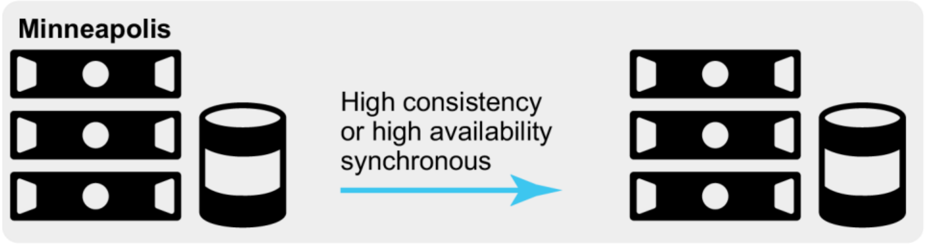


Figure 26 DR within a campus, standard topology, Fibre Channel replication

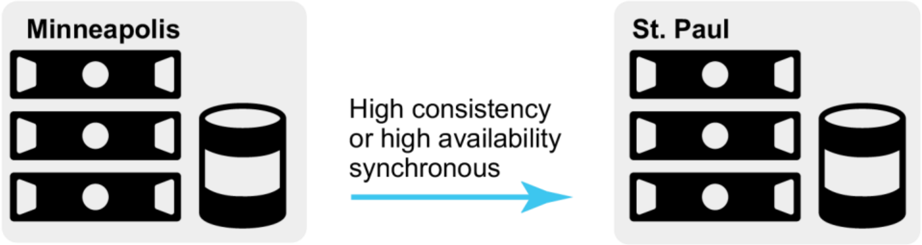


Figure 27 Metro DR site, standard topology, Fibre Channel replication

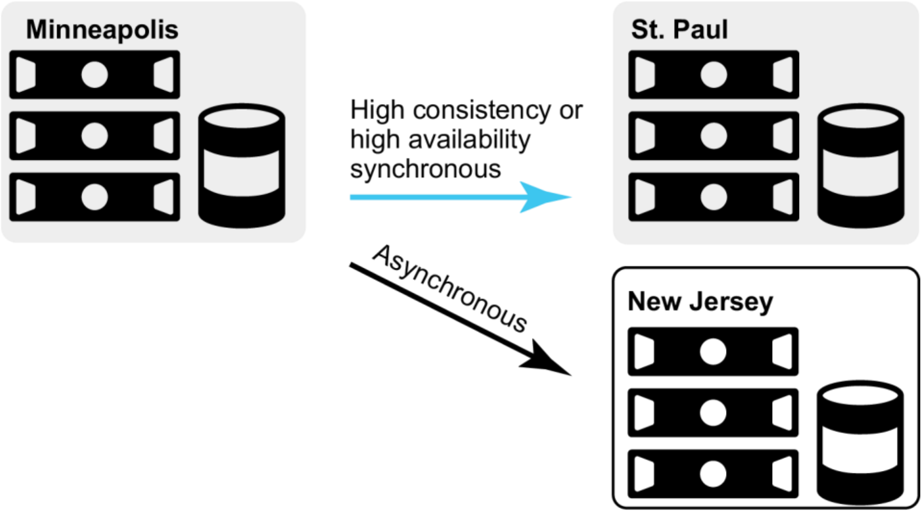


Figure 28 Metro and remote DR sites, mixed topology (1-to-N), Fibre Channel and iSCSI replication

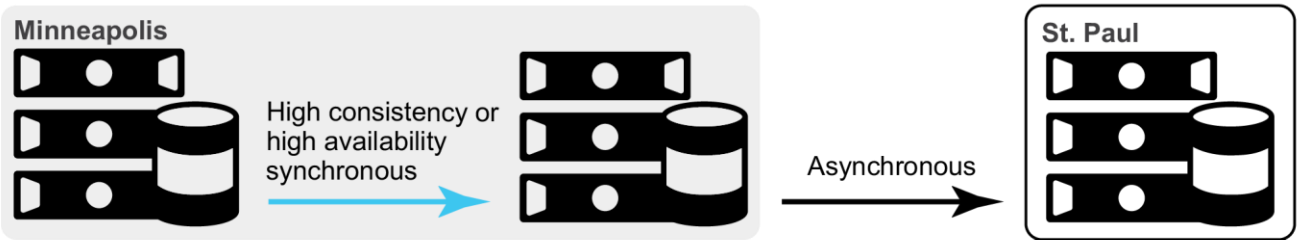


Figure 29 Intra campus and metro DR sites, cascade topology, Fibre Channel and iSCSI replication

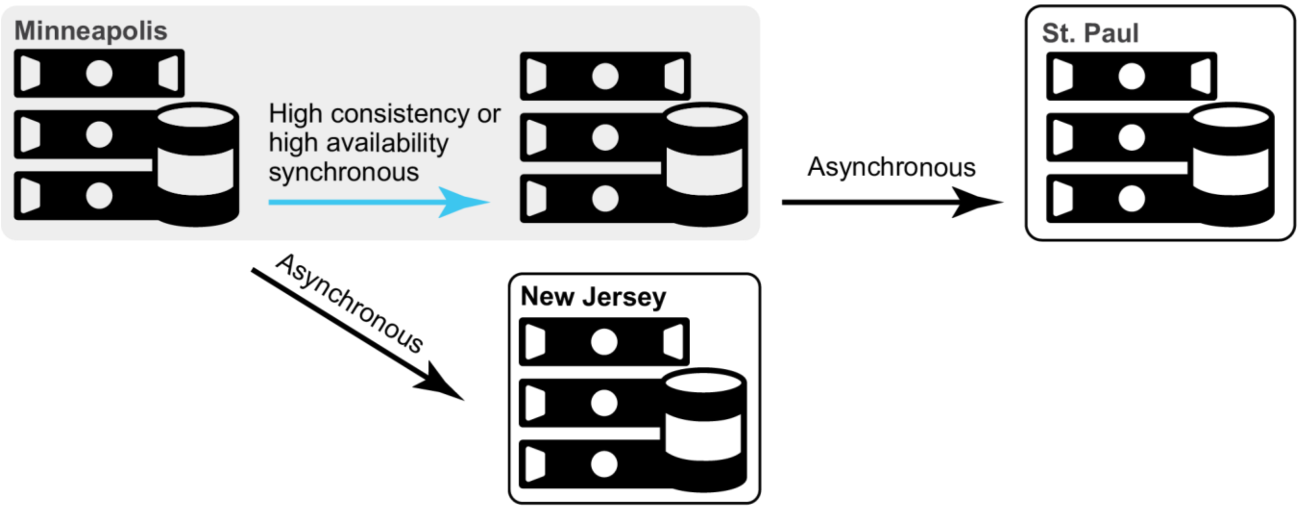


Figure 30 Intra-campus, metro, and remote DR sites; hybrid topology; Fibre Channel and iSCSI replication

The examples in Figure 26 through Figure 30 serve to represent physical hosts or virtual machines. Some notable details in the examples are:

- A 1U DSM server is racked at each recovery site to facilitate DR testing and cutover automation through DSM, VMware Site Recovery Manager, or both. The DSM shown is for logical representation only. DSM may be a virtual machine.
- SC Series storage supports Fibre Channel and iSCSI-based replication.
- SC Series storage supports asynchronous replication as well as multiple modes of synchronous replication.
- Either mode of synchronous replication latency will impact production applications relying on the replication source volume. The infrastructure design should be sized for adequate replication bandwidth, controllers, and storage at the recovery site to efficiently absorb throughput.
- The examples provide adequate hardware and data center redundancy at the recovery site when implementing high consistency synchronous replication. Aside from a pause operation, unavailability of a destination replica volume leads to unavailability of the source volume and will result in a production application outage.

5 Live Volume overview

Live Volume is a high availability and data mobility feature for SC Series storage that builds on the Dell Fluid Data™ architecture. It enables non-disruptive data access, data migration, and stretched volumes between SC Series arrays. It also provides the storage architecture and automatic failover required for VMware vSphere Metro Storage Cluster certification (vMSC) with SCOS 6.7 and newer. SCOS 7.1 extended Live Volume automatic failover (LV-AFO) support to Microsoft Server 2012/Hyper-V 2012 and newer clusters.

5.1 Reference architecture

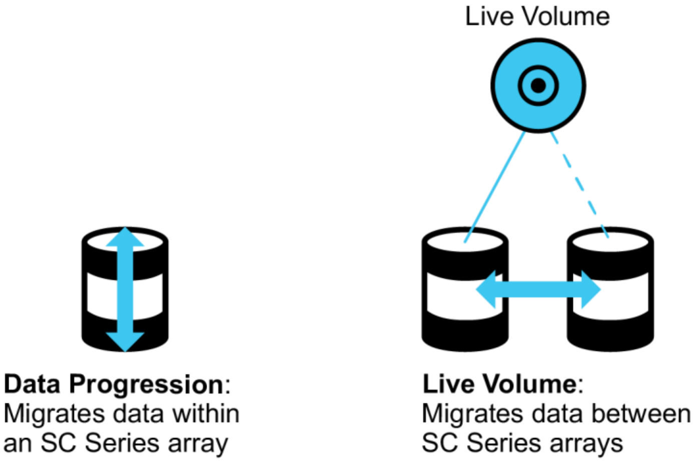

Live Volume
Data Progression: Migrates data within an SC Series array
Live Volume: Migrates data between SC Series arrays

Figure 31 Live Volume migration

Live Volume is a software-defined high availability solution that is integrated into the SC Series controllers. It is designed to operate in a production environment that allows storage hosts and applications to remain operational during planned volume migration or data movement regardless of the geographical distance between arrays. The automatic failover and restore features available for vSphere Metro Storage Cluster integration with SCOS 6.7 and newer, and for Microsoft environments with SCOS 7.1 and newer, provides high availability for applications and services during planned or unplanned events in the data center.

Live Volume increases operational efficiency, eliminates the need for planned storage outages, and enables planned migrations as well as disaster avoidance and disaster recovery. The Live Volume feature provides powerful options:

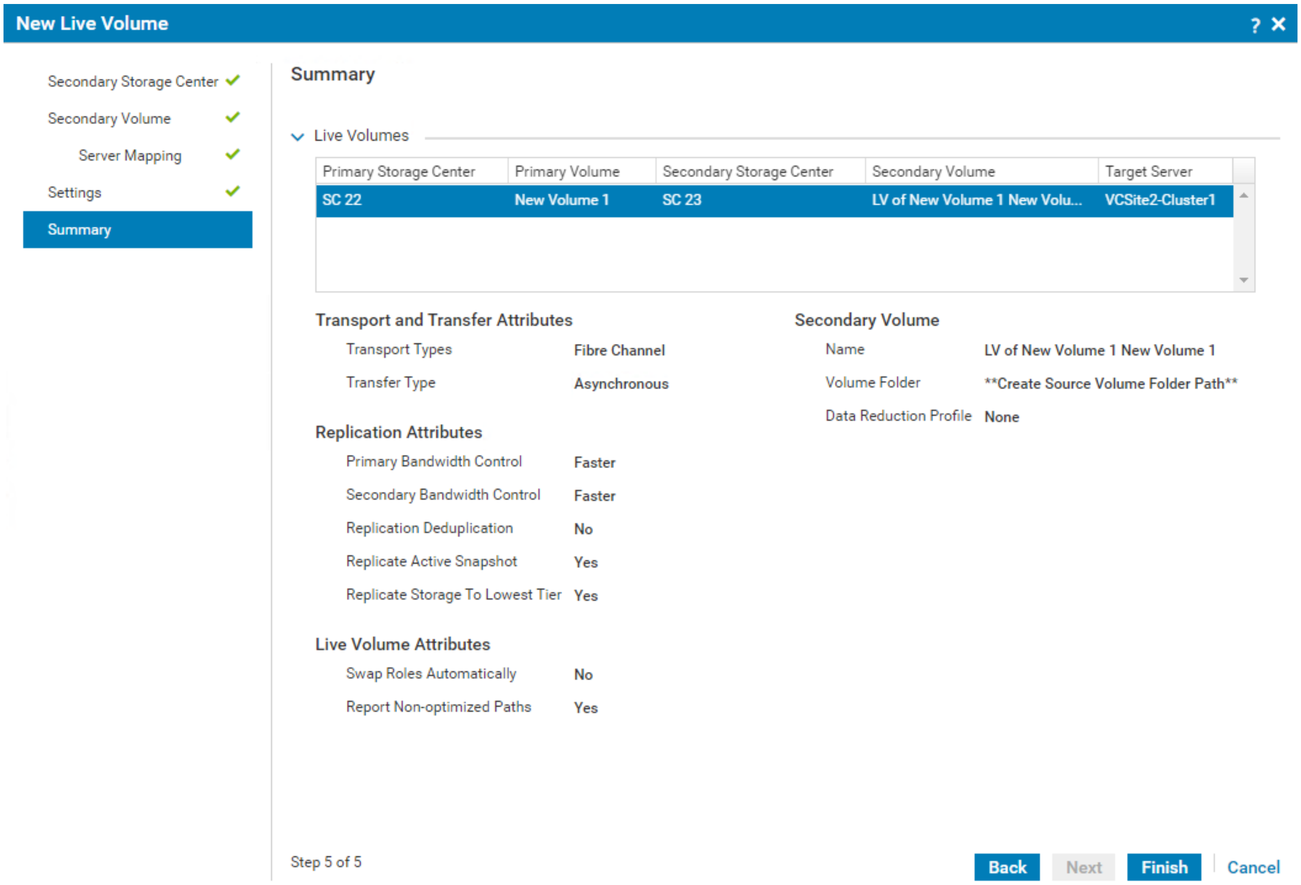
- Allows storage to follow mobile virtual machines and applications in virtualized environments within a data center, campus, or across larger distances
- Supports automatic or manual mechanisms to migrate virtual machine storage as virtual machines are migrated within or across hypervisor clusters
- Zero application downtime occurs for planned maintenance outages
- Enables all data to be moved non-disruptively between arrays to achieve full planned or unplanned site shutdown without downtime
- Provides on-demand load balancing; Live Volume enables data to be relocated as desired to distribute workload between arrays
- Stretches Microsoft clustered volumes between geographically disperse locations
- Allows VMware vSphere and Microsoft Clusters to see the same disk signature on the volume between data centers and allows the volume to be clustered across arrays

- Supports asynchronous or synchronous replication and included features such as:
  - Snapshots
  - High consistency and high availability modes
  - Mode migration
  - DR activation for Live Volume managed replications
- Supports an additional asynchronous or synchronous Live Volume replication to a third array created and dynamically managed by Live Volume
- Provides automatic or manual Live Volume failover and restore in the event of an unplanned outage at a primary Live Volume site
- Includes VMware vSphere Metro Storage Cluster (vMSC) certification with SCOS 6.7 and newer

Live Volume is designed to fit into existing physical and virtual environments without disruption or significant changes to existing configurations or workflow. Physical and virtual servers see a consistent, unchanging virtual volume. Volume presentation is consistent and transparent before, during, and after migration. The Live Volume role swap process can be managed automatically or manually and is fully integrated into the array and Dell Storage Manager. Live Volume operates asynchronously or synchronously and is designed for application high availability during planned migration, resource balancing, disaster avoidance, and disaster recovery use cases.

A Live Volume can be created between two SC Series arrays residing in the same data center or between two well-connected data centers with Fibre Channel or iSCSI replication connectivity.

Using Unisphere Central for SC Series, a Live Volume and an optional Live Volume managed replication can be created. For more information on creating a Live Volume, see the appropriate *Dell Storage Manager User Guide* provided with the DSM software.



Summary

Live Volumes

Primary Storage Center	Primary Volume	Secondary Storage Center	Secondary Volume	Target Server
SC 22	New Volume 1	SC 23	LV of New Volume 1 New Volu...	VCSite2-Cluster1

Transport and Transfer Attributes

Transport Types	Fibre Channel
Transfer Type	Asynchronous

Replication Attributes

Primary Bandwidth Control	Faster
Secondary Bandwidth Control	Faster
Replication Deduplication	No
Replicate Active Snapshot	Yes
Replicate Storage To Lowest Tier	Yes

Live Volume Attributes

Swap Roles Automatically	No
Report Non-optimized Paths	Yes

Secondary Volume

Name	LV of New Volume 1 New Volume 1
Volume Folder	**Create Source Volume Folder Path**
Data Reduction Profile	None

Step 5 of 5

Figure 32 Creating a Live Volume

5.2 Proxy data access

An SC Series Live Volume is comprised of a pair of replication enabled volumes: a primary Live Volume and a secondary Live Volume. A Live Volume can be accessed through either array supporting the Live Volume replication. However, the primary Live Volume role can only be active on one of the available arrays. All read and write activity for a Live Volume is serviced by the array hosting the primary Live Volume. If a server is accessing the Live Volume through uniform or non-uniform paths to the secondary Live Volume array, the I/O is passed through the Fibre Channel or iSCSI replication link to the primary Live Volume system.

In Figure 33, a mapped server is accessing a Live Volume by proxy access through the secondary Live Volume system to the primary Live Volume system. This type of proxy data access requires the replication link between the two arrays to have enough bandwidth and minimum latency to support the I/O operations and latency requirements of the application data access.

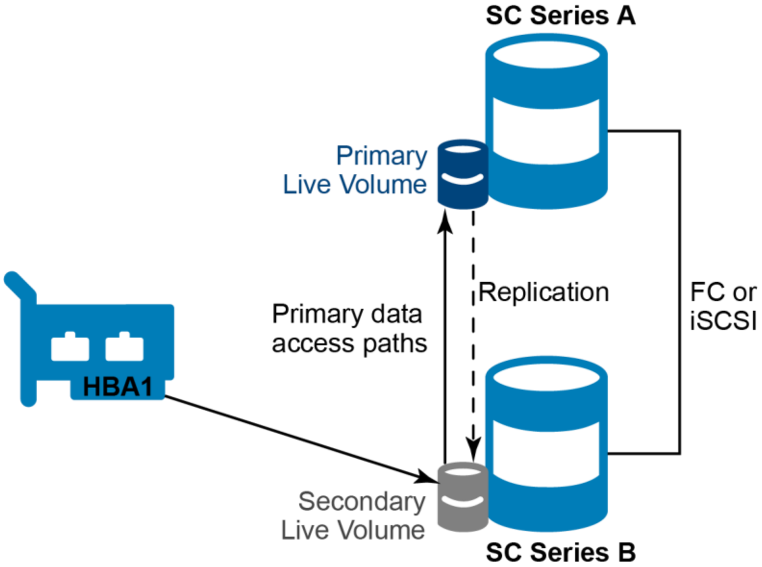


Figure 33 Proxy data access through the Secondary Live Volume

5.3 Live Volume ALUA

The Live Volume Asymmetric Logical Unit Access (ALUA) feature was added in SCOS 7.3 and DSM 2018 following the T10 SCSI-3 specification SPC-3 for Microsoft Windows, Hyper-V, and vSphere operating systems. The feature is enabled on a per-Live-Volume basis and allows the advertisement of MPIO paths to the primary Live Volume as optimal and MPIO paths to the secondary Live Volume as non-optimal. When used in conjunction with an ALUA-supporting Round Robin path selection policy (PSP), optimal paths will be used for read and write I/O when available while non-optimal paths will be reserved for use in the event no optimal paths are available. If a Live Volume role swap or Automatic Failover occurs, the SC Series array will report the ALUA path state changes to the storage host upon request. The feature effectively allows a Round Robin PSP to be used with Live Volume in either uniform or non-uniform storage presentations. The Round Robin PSP is easy to deploy, requires minimal administrative effort and documentation, and yields a good balance of storage port, fabric, and controller utilization.

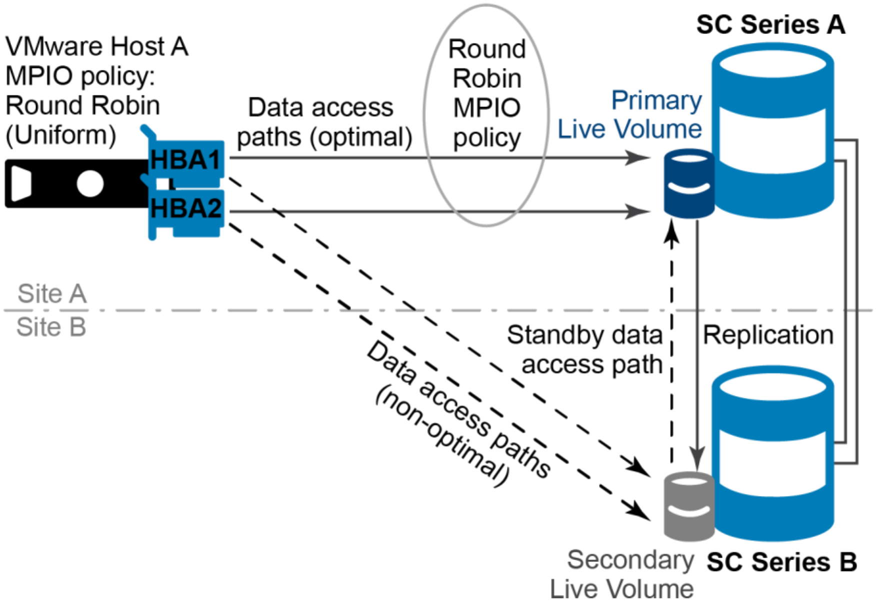
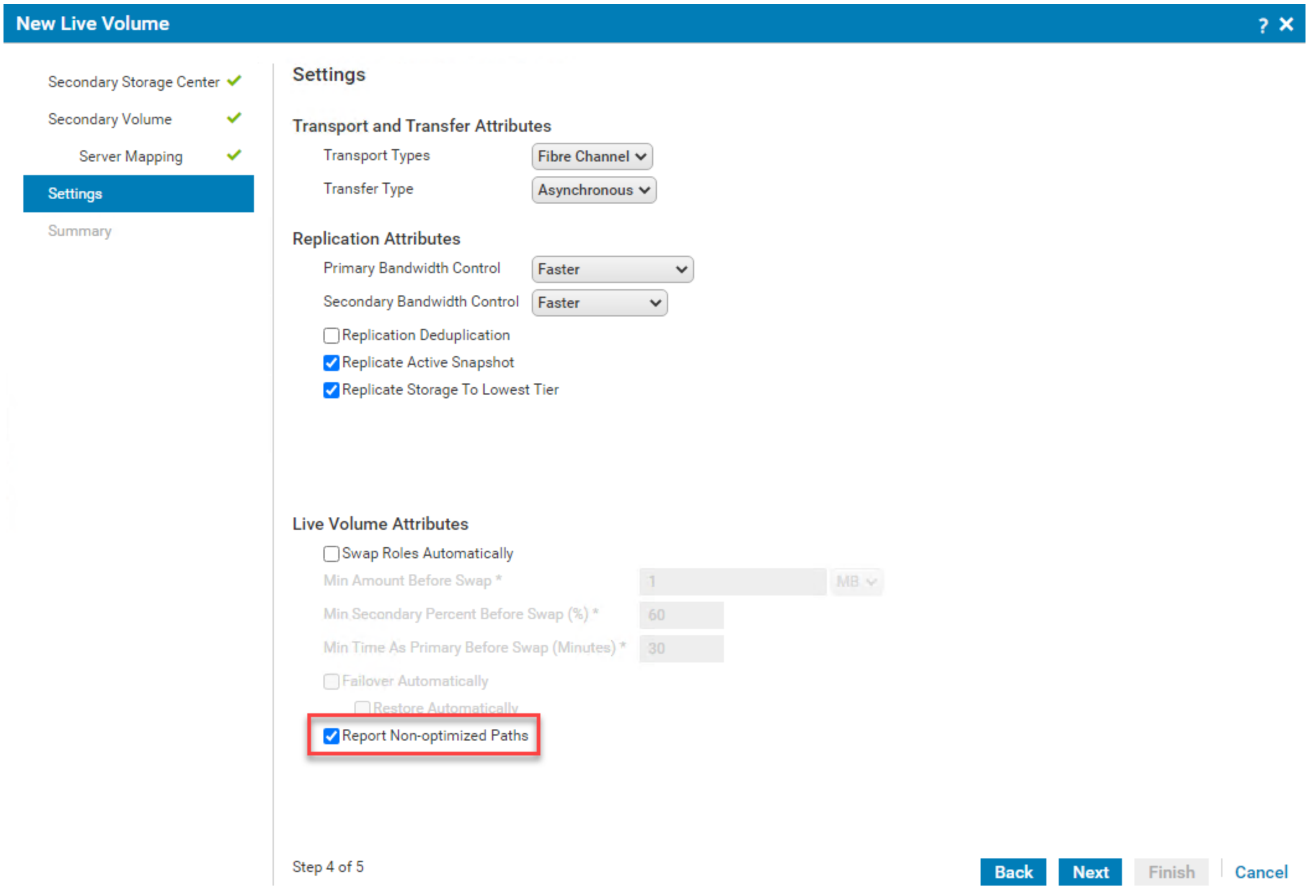


Figure 34 Uniform Live Volume with ALUA and Round Robin PSP

ALUA can be enabled on Live Volumes when both SC Series arrays are running SCOS 7.3 or newer. For new Live Volumes, select the Live Volume option to enable **Report Non-optimized Paths**.


New Live Volume

Settings

Transport and Transfer Attributes

Transport Types: Fibre Channel

Transfer Type: Asynchronous

Replication Attributes

Primary Bandwidth Control: Faster

Secondary Bandwidth Control: Faster

☐ Replication Deduplication

☑ Replicate Active Snapshot

☑ Replicate Storage To Lowest Tier

Live Volume Attributes

☐ Swap Roles Automatically

Min Amount Before Swap *: 1 MB

Min Secondary Percent Before Swap (%) *: 60

Min Time As Primary Before Swap (Minutes) *: 30

☐ Failover Automatically

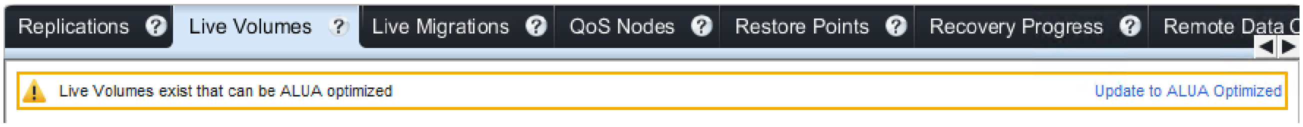
☐ Restore Automatically

☑ Report Non-optimized Paths

Step 4 of 5

Figure 35 Select Report Non-optimized Paths for the secondary Live Volume

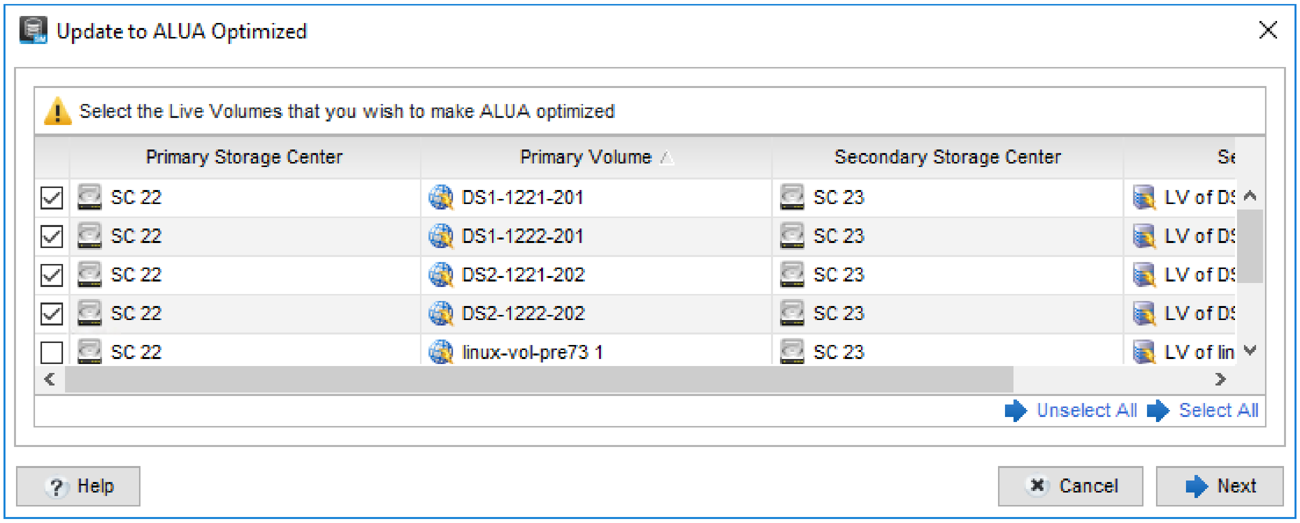
For pre-existing Live Volumes, once both SC Series arrays are upgraded to SCOS 7.3, a banner will be displayed allowing these Live Volumes to upgraded to support ALUA capability.



Live Volumes exist that can be ALUA optimized

Figure 36 Banner in DSM 2018 showing Live Volumes can be upgraded for ALUA capability

Dell Storage Manager 2018 and newer provides guidance through the upgrade process. All Live Volumes can be upgraded, or just a partial subset of Live Volumes can be upgraded if not all storage host operating system types meet the requirements.

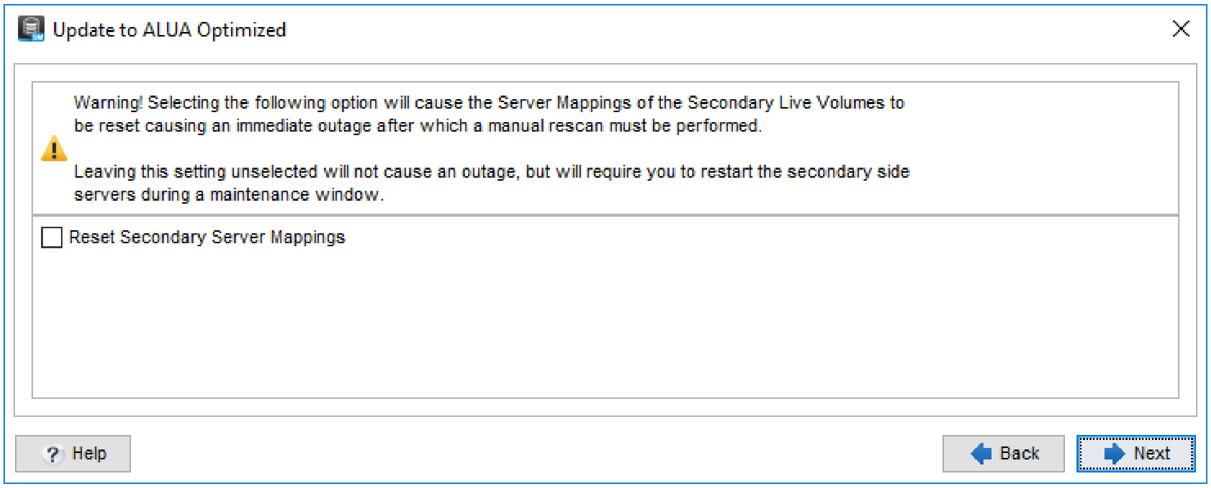


Select the Live Volumes that you wish to make ALUA optimized

	Primary Storage Center	Primary Volume	Secondary Storage Center	Se
☑	SC 22	DS1-1221-201	SC 23	LV of DS
☑	SC 22	DS1-1222-201	SC 23	LV of DS
☑	SC 22	DS2-1221-202	SC 23	LV of DS
☑	SC 22	DS2-1222-202	SC 23	LV of DS
☐	SC 22	linux-vol-pre73 1	SC 23	LV of lin

Figure 37 Microsoft Windows, Hyper-V, or vSphere Live Volumes can be upgraded for ALUA capability

The next task in the wizard provides an option to unmap and remap the secondary Live Volume mappings to the storage host. Depending on the operating system of the storage host, resetting the secondary Live Volume mappings, or alternatively rebooting the storage host, may be necessary to cleanly pick up the ALUA state changes on the Live Volume. This is a flexible option available to the administrator performing the upgrade. Be aware of the impact of either operation. Testing revealed that vSphere hosts require a reboot. The default action in the workflow is to not reset the secondary server mappings.



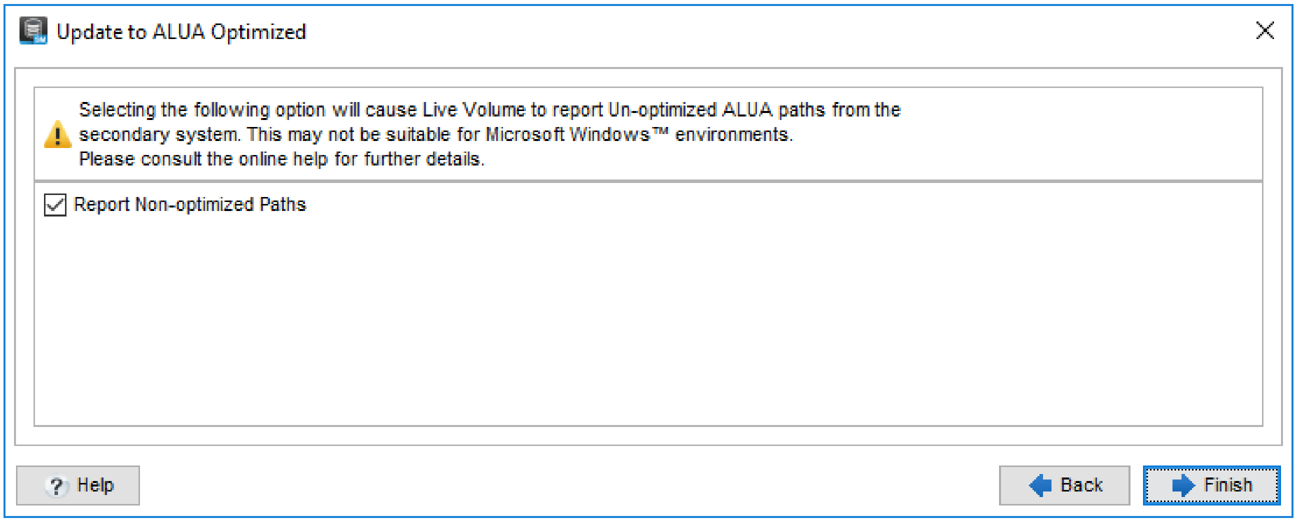
Warning! Selecting the following option will cause the Server Mappings of the Secondary Live Volumes to be reset causing an immediate outage after which a manual rescan must be performed.

Leaving this setting unselected will not cause an outage, but will require you to restart the secondary side servers during a maintenance window.

☐ Reset Secondary Server Mappings

Figure 38 Reset the secondary Live Volume mappings or reboot the storage host as necessary

After the Live Volume is upgraded for ALUA capability, the last step is to choose whether or not to **Report Non-optimized Paths**. The default action is to report non-optimized paths. However, if the storage host operating system does not support ALUA but there is a desire to upgrade the Live Volume for ALUA support, this option allows leaving the ALUA feature disabled from the viewpoint of the storage host operating system.



Selecting the following option will cause Live Volume to report Un-optimized ALUA paths from the secondary system. This may not be suitable for Microsoft Windows™ environments.
Please consult the online help for further details.

☑ Report Non-optimized Paths

Figure 39 Report Non-optimized Paths option

Live Volumes which were upgraded for ALUA capability or created in SCOS 7.3 and natively have ALUA capability cannot be downgraded or have their ALUA capability removed. However, the ALUA feature can be disabled at any time by editing the Live Volume and unchecking the Report Non-Optimized Paths option.

5.4 Live Volume connectivity requirements

Live Volume connectivity requirements vary depending on intended use. For example, there are different requirements for using Live Volume to migrate a workload depending on whether or not the virtual machines are powered on during the migration.

From the Live Volume perspective and outside of automatic failover with vSphere Metro Storage Cluster or Microsoft Server/Hyper-V clusters, there are no firm restrictions on bandwidth or latency. However, to proxy data access from one SC Series array to another requires the Live Volume arrays to be connected through a high-bandwidth, low-latency replication link. Some operating systems and applications require disk latency under 10 ms for optimal performance. However, performance impact may not be effectively realized until disk latency reaches 25 ms or greater. Some applications are more latency sensitive. This means that if average latency in the primary data center to the storage is 5 ms for the volume and the connection between the two data centers averages 30 ms of latency, the storage latency writing data to the primary Live Volume from the secondary Live Volume proxy across the link is probably going to be 35 ms or greater. While this may be tolerable for some applications, it may not be tolerable for others.

If the Live Volume proxy communication or synchronous replication is utilized, it is strongly recommended to leverage site-to-site replication connectivity which offers consistent bandwidth and the least amount of latency. The amount of bandwidth required for the connectivity is highly dependent on the amount of changed data that requires replication, as well as the amount of other traffic on the same wire. If a site is not planning to proxy data access between arrays with asynchronous replication, then latency is not as much of a concern.

It is recommended to use dedicated VLANs or fabrics to isolate IP-based storage traffic from other types of general-purpose LAN traffic, especially when spanning data centers. While this is not a requirement for Live Volume, it is a general best practice for IP-based storage.

For hypervisor virtualization products such as VMware vSphere, Microsoft Hyper-V, and Citrix® XenServer®, a site must have at least a 1 GB connection with 10 ms or less latency between servers to support VMware vMotion® Metro or live migration activities. Standard vMotion requires 5 ms or less latency between the source and destination host.

5.4.1 High bandwidth, low latency

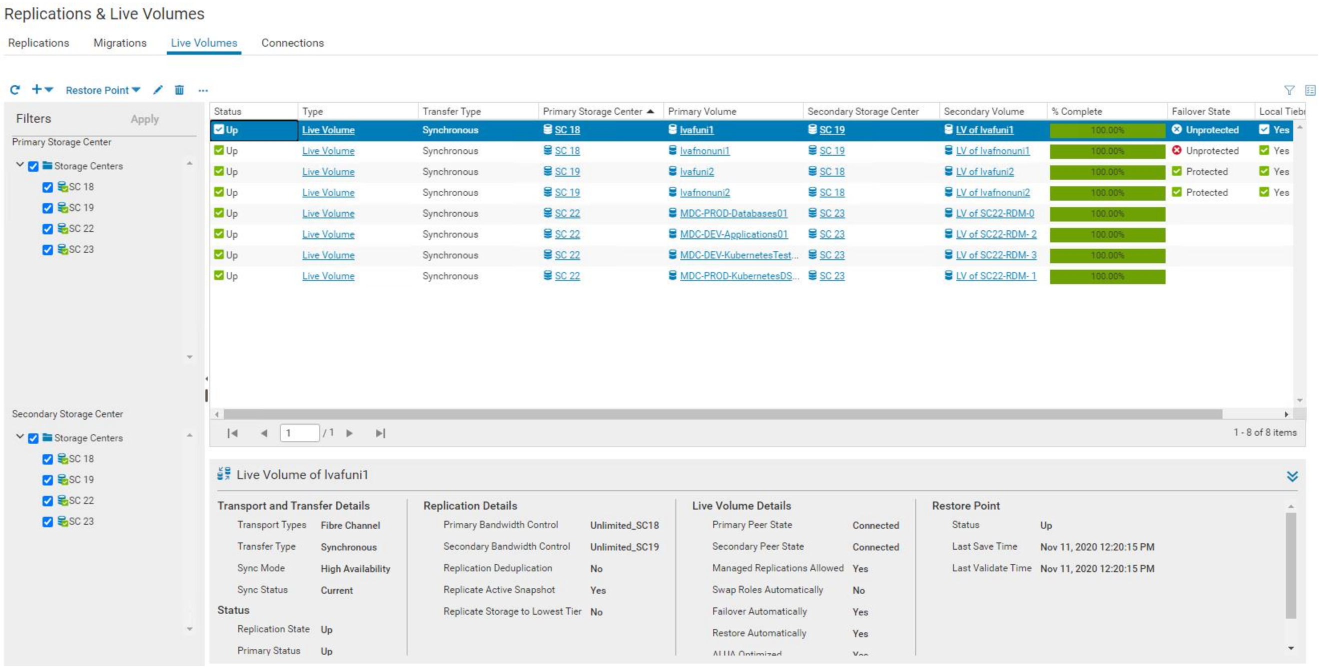
For an inter-data-center, campus environment (or within a 60-mile radius as an example), high-speed fiber connectivity is possible. While inter-data-center and campus environments may be able to run fiber speeds of up to 16 Gb using Multi-mode fiber connectivity, single-mode fiber connectivity of up to 1 Gb using dark fibre can assist with connecting data centers together that may be up to 60 miles apart as an example. Minimal latency is especially key when implementing Live Volume on top of synchronous replication (in either mode). This type of connectivity is highly recommended for live migrating virtual machine workloads between arrays and required for synchronous Live Volume with automatic failover used in vSphere Metro Storage Cluster configurations or Microsoft Windows Server/Hyper-V clusters.

5.4.2 Low bandwidth, high latency

If a site is planning on using Live Volume on a low-bandwidth, high-latency replication link, it is recommended to control swap role activities manually by shutting down the application running at site A, perform a Live Volume swap role, and then bring the application up at the remote site. This scenario prevents any storage proxy traffic from going across the link, as well as providing a pause in replication I/O for the link allowing the replication to catch up so that a Live Volume swap role can occur as quickly as possible. Manual swap role activities can be controlled by deselecting the **Automatically Swap Roles** option on the Live Volume configuration. If the replication connection has characteristics of high latency, asynchronous replication is recommended for Live Volume so that applications are not adversely impacted by replication latency. Note that Live Volume automatic failover supports synchronous replication in high availability mode only.

5.5 Replication and Live Volume attributes

Once a Live Volume is created, additional attributes can be viewed and modified in Unisphere Central for SC Series as depicted in Figure 40.



Status	Type	Transfer Type	Primary Storage Center ▲	Primary Volume	Secondary Storage Center	Secondary Volume	% Complete	Failover State	Local Tiebr
☑ Up	Live Volume	Synchronous	SC 18	lvafuni1	SC 19	LV of lvafuni1	100.00%	☒ Unprotected	☑ Yes
☑ Up	Live Volume	Synchronous	SC 18	lvafnonuni1	SC 19	LV of lvafnonuni1	100.00%	☒ Unprotected	☑ Yes
☑ Up	Live Volume	Synchronous	SC 19	lvafuni2	SC 18	LV of lvafuni2	100.00%	☑ Protected	☑ Yes
☑ Up	Live Volume	Synchronous	SC 19	lvafnonuni2	SC 18	LV of lvafnonuni2	100.00%	☑ Protected	☑ Yes
☑ Up	Live Volume	Synchronous	SC 22	MDC-PROD-Databases01	SC 23	LV of SC22-RDM-0	100.00%		
☑ Up	Live Volume	Synchronous	SC 22	MDC-DEV-Applications01	SC 23	LV of SC22-RDM- 2	100.00%		
☑ Up	Live Volume	Synchronous	SC 22	MDC-DEV-KubernetesTest...	SC 23	LV of SC22-RDM- 3	100.00%		
☑ Up	Live Volume	Synchronous	SC 22	MDC-PROD-KubernetesDS...	SC 23	LV of SC22-RDM- 1	100.00%		

1 / 1 — 1 - 8 of 8 items

Live Volume of lvafuni1

Transport and Transfer Details

Transport Types	Fibre Channel
Transfer Type	Synchronous
Sync Mode	High Availability
Sync Status	Current

Status

Replication State	Up
Primary Status	Up

Replication Details

Primary Bandwidth Control	Unlimited_SC18
Secondary Bandwidth Control	Unlimited_SC19
Replication Deduplication	No
Replicate Active Snapshot	Yes
Replicate Storage to Lowest Tier	No

Live Volume Details

Primary Peer State	Connected
Secondary Peer State	Connected
Managed Replications Allowed	Yes
Swap Roles Automatically	No
Failover Automatically	Yes
Restore Automatically	Yes
ALUA Optimized	Yes

Restore Point

Status	Up
Last Save Time	Nov 11, 2020 12:20:15 PM
Last Validate Time	Nov 11, 2020 12:20:15 PM

Figure 40 Live Volume settings

5.5.1 Replication

Live Volume is built on standard SC Series storage replicated volumes in which each replicated volume can individually be configured as asynchronous, synchronous high availability, or synchronous high consistency. Note that Live Volume automatic failover requires synchronous high availability mode. More information about these attributes can be found throughout this document and in the *Dell Storage Manager Administrator's Guide*.

Type: This refers to asynchronous or synchronous replication.

Sync Mode: If the replication type is synchronous, Sync Mode describes the mode of synchronous replication that may be either high consistency or high availability. Sync Mode is not displayed for asynchronous Live Volumes.

Sync Status: If the replication type is synchronous, Sync Status describes the current state of the synchronous replication as Current or Out Of Date. When Sync Status is Current, synchronous replication is in sync. This means that both the source and destination volumes are consistent and the cumulative latency to the secondary Live Volume will be observed at the primary Live Volume application. An out-of-date status indicates that the data on the source and destination volumes is not consistent. Changed or inconsistent data is tracked in a journal where the primary Live Volume resides until the two volumes are once again Current. Sync Status is not displayed for asynchronous Live Volumes.

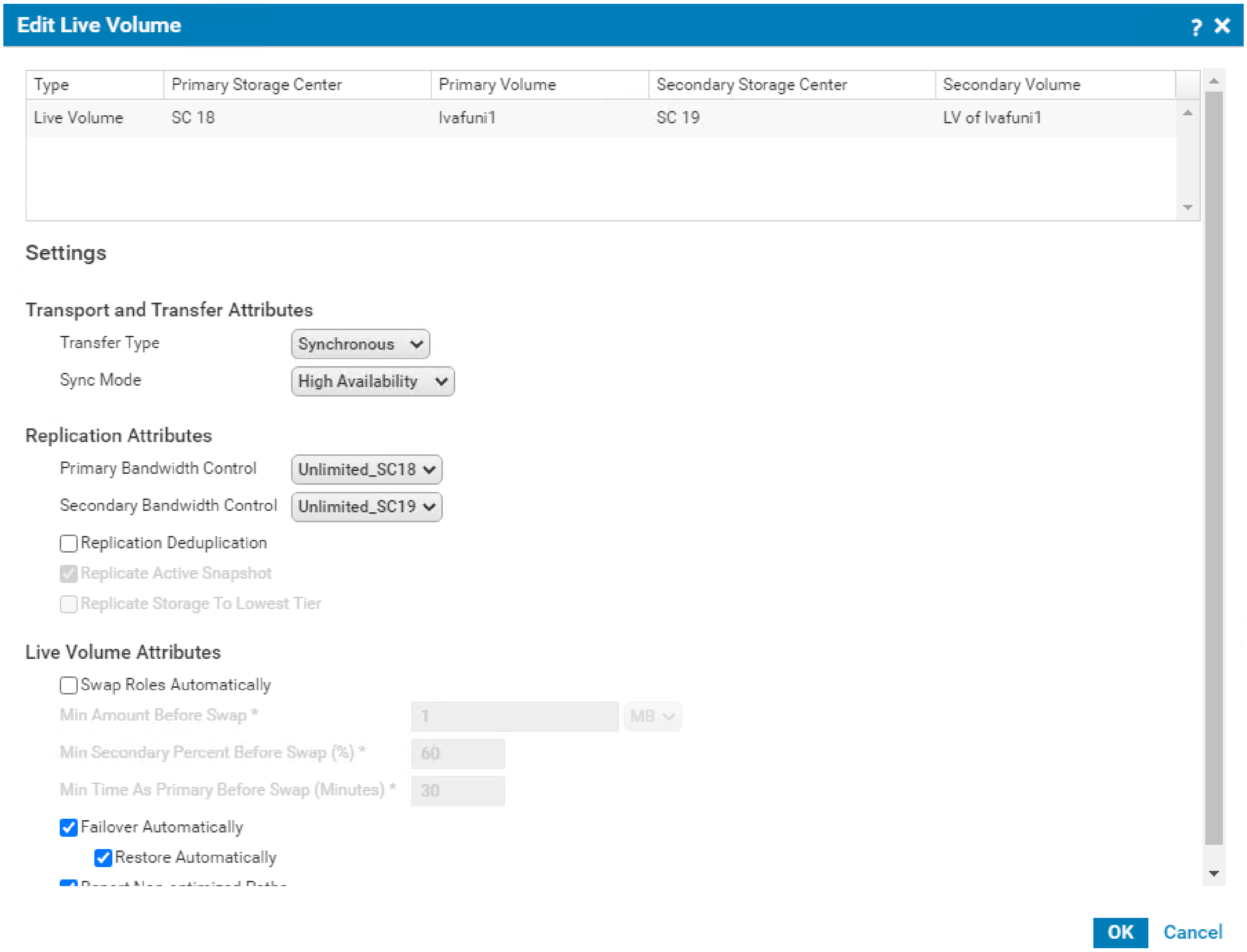
Deduplication: The Deduplication feature replicates only the changed portions of the snapshot history on the source volume, rather than all data captured in each snapshot. While this is a more processor-intensive activity, it may reduce the amount of replication traffic and bandwidth required. If sufficient bandwidth is present on the connection, Dell Storage recommends disabling Deduplication for Live Volumes in order to preserve controller CPU time for other processes.

Replicate Active Snapshot: It is recommended that Replicate Active Snapshot is enabled for asynchronous Live Volumes. This ensures that data is replicated in real time as quickly as possible which decreases the amount of time required to perform a Live Volume Swap role. For Live Volumes configured with either mode of synchronous replication, the Active Snapshot is effectively replicated in real time providing the replication is in sync (HA mode) and not paused by an administrator (HA and HC modes).

Replicate Storage to Lower Tier: The Replicate Storage to Lowest Tier feature is automatically enabled for a new Live Volume. Disable this option to replicate data to tier 1 on the destination array. Many users perform the initial Live Volume replication to the lowest tier, and then deselect this option once the initial replication completes. This strategy aids in preserving tier 1 storage capacity, which is useful when using SSD or 15K drives. For more information on Data Progression with Live Volume, see the section, Data Progression and Live Volume.

QoS Nodes: A pair of QoS Nodes depicts the desired egress traffic shaping to be applied when replicating from the primary to the secondary Live Volume. Although labeled a secondary QoS Node, it does not provide ingress traffic shaping. Instead, it provides egress traffic shaping after a role swap occurs and it becomes the primary Live Volume. QoS Nodes apply to replication traffic only. The Live Volume proxy traffic between the arrays is not governed by QoS Nodes. If the link between the Live Volume storage controllers is shared by other traffic, it may be necessary to throttle the replication traffic using QoS Nodes to prevent it from flooding the replication link. However, throttling synchronous replication traffic will produce latency for applications which are dependent on the Live Volume. For this reason, replication links and QoS Nodes should be sized appropriately taking into account the amount of data per Live Volume, rate of change, application latency requirements, and any other applications or services that may be sharing the replication link. This is especially important when using synchronous replication. Note that vSphere Metro Storage Cluster latency between sites should not exceed 10 ms.

For instance, if a 20 Gbps replication link exists between data centers that is shared by all intra-data-center traffic, a replication QoS could be set at 10 Gbps and thereby limits the amount of bandwidth used by replication traffic to half of the pipe capacity. This allows the other non-Live-Volume replication traffic to receive a reasonable share of the replication pipe, but could cause application latency if synchronous replication traffic exceeds 1,000 MBps.



Edit Live Volume

Type	Primary Storage Center	Primary Volume	Secondary Storage Center	Secondary Volume
Live Volume	SC 18	lvafuni1	SC 19	LV of lvafuni1

Settings

Transport and Transfer Attributes

Transfer Type: Synchronous

Sync Mode: High Availability

Replication Attributes

Primary Bandwidth Control: Unlimited_SC18

Secondary Bandwidth Control: Unlimited_SC19

☐ Replication Deduplication

☑ Replicate Active Snapshot

☐ Replicate Storage To Lowest Tier

Live Volume Attributes

☐ Swap Roles Automatically

Min Amount Before Swap *: 1 MB

Min Secondary Percent Before Swap (%) *: 60

Min Time As Primary Before Swap (Minutes) *: 30

☑ Failover Automatically

☑ Restore Automatically

☑ Report Non-optimized Paths

Figure 41 Editing a Live Volume with QoS nodes

As a best practice, common QoS Nodes should not be shared between a single SC Series source and multiple SC Series destinations, particularly where Live Volume managed replications are in use. For instance, if volume A is replicating to volume B synchronously to support a Live Volume and volume A is also replicating to volume C asynchronously to support a Live Volume managed replication, an independent QoS Node should be created and used for each of these replications.

5.5.2 Live Volume

A Live Volume provides additional attributes that control the behavior of the Live Volume and are listed as follows:

Swap Roles Automatically: When Swap Roles Automatically is selected, the primary Live Volume will be automatically swapped to the array serving the most I/O load to that Live Volume as long as it meets the conditions for a swap. The Live Volume logic gathers I/O samples to determine the primary access to the Live Volume (from either servers accessing it directly on the primary Live Volume array, or servers accessing from a secondary Live Volume array). Samples are taken every 30 seconds and automated role-swap decisions are based on the last ten samples (five minutes total). This occurs continuously on the primary Live Volume array (it does not start once the 30-minute delay timer expires).

The autoswap design is meant to make intelligent decisions on the autoswap movement of Live Volume primary systems while preventing role swap movement from occurring rapidly back and forth between arrays.

Min Amount Before Swap: This attribute is the amount of data accessed from a secondary system. If there is light, infrequent access to a Live Volume from a secondary array, consider if this makes sense to move the primary to that system. If so, set this value to a very small value. The criteria for this aspect are defined by the Min Amount Before Swap attribute for the Live Volume. The value specifies an amount equal to the read/write access divided by the second-per-sample value. If a sample shows that the secondary array access exceeds this value, this sample/aspect has been satisfied.

Min Secondary Percent Before Swap: This is the percentage of total access of a Live Volume from the secondary array on a per-sample basis. The criteria for this aspect are defined by the Min Secondary Percent for Swap attribute for the Live Volume. If a sample shows the secondary array accessed the Live Volume more than the defined setting for this aspect, this sample/aspect has been satisfied. The default setting for this option is 60%. The SC Series array takes samples every 30 seconds and keeps the most recent ten samples (five minutes total) for analysis. This means that the secondary Live Volume has to have more I/O than the primary system for six out of ten samples (60%).

Min Time As Primary Before Swap: Each Live Volume has a TimeAsPrimary timer (default setting of 30 minutes) that will prohibit an autoswap from occurring after a role swap has completed. This means that following a role swap of a Live Volume (either auto or user specified), the SC Series array waits the specified amount of time before analyzing data for autoswap conditions to be met again. The purpose of this is to prevent thrashing of autoswap in environments where the primary access point could be dynamic or where a Live Volume is shared by applications that can be running on servers both at the primary and secondary sites.

Failover Automatically: This indicates whether or not the Live Volume is configured to automatically fail over and remain available if there is an unplanned outage of the primary Live Volume.

ALUA Optimized: This specifies whether the Live Volume is capable of supporting ALUA Non-Optimized path reporting. All new Live Volumes created between SC Series arrays running SCOS 7.3 or newer will automatically be ALUA Optimized. Live Volumes created on SC Series arrays with SCOS 7.2 or earlier can be updated to be ALUA Optimized once both arrays are running SCOS 7.3 or newer. Live Volumes running on SCOS 7.2 or earlier will not be ALUA Optimized. Live Volumes which are not ALUA Optimized will report an Optimal path status for all paths to both the primary and secondary Live Volume.

Report Non-Optimized Paths: This indicates whether or not the Live Volume is configured to report Non-Optimized paths to the secondary Live Volume (enabled by default). This feature is used in conjunction with uniform storage presentation and a Round Robin path selection policy where optimal MPIO paths will be preferred over non-optimal paths for I/O when both types are available. Live Volumes must be ALUA Optimized and the box must be checked in the Live Volume settings in order to report Non-Optimized paths to the secondary Live Volume.

6 Data Progression and Live Volume

Data Progression lifecycles are storage profiles that are managed independently on each SC Series array configured with Live Volume. If a Live Volume is not replicated to the lowest tier on the destination array, data ingestion follows the volume-based storage profile. The Data Progression lifecycle on the destination array then moves data based on the destination storage profile. If a Live Volume is replicated to the lowest tier on the destination array, data ingestion occurs in the lowest tier of storage. The Data Progression lifecycle on the destination array then moves data based on the destination storage profile.

6.1 Primary and secondary Live Volume

If a primary Live Volume is located on volume A and is not being replicated to the lowest tier on the destination volume B, the data will progress down on the destination array to the next tier or RAID level every 12 days. This is because the data on the destination array is never actually being read. All reads take place on the primary Live Volume array.

For instance, if an array has two tiers of storage and the storage profiles write data at RAID 10 on tier 1, snapshot data at tier 1 is at RAID 5, and tier 3 is at RAID 5. The blocks of data that were written during the day will progress from tier 1, RAID 10 to tier 1, RAID 5 on the first night.

If a primary Live Volume is frequently swapped between the Live Volume arrays, then the Data Progression pattern will be determined by how often the data is accessed on both systems.

7 Live Volume and MPIO

By using Live Volume with a storage host that has access to both SC Series arrays in a Live Volume configuration, multiple paths can be presented to the server across the arrays. All read and write I/O ultimately flows to the primary Live Volume. Read and write I/O sent down paths to the primary Live Volume are handled directly. Read and write I/O sent down paths to the secondary Live Volume are proxied to the primary Live Volume via replication ports. Acknowledgements and read payloads are then sent back over the replication ports, through the secondary Live Volume, and back down the originating path to the storage host. ALUA requires special consideration to understand and optimize I/O paths for the Live Volume.

Note: Live Volume ALUA support was added in SCOS 7.3 for VMware vSphere and Microsoft Windows operating systems only.

7.1 MPIO policies for Live Volume

For Live Volume arrays where a server has volume access through both the primary and secondary Live Volume controllers (uniform storage presentation), it may be desirable to configure the MPIO policy to prevent primary data access through the secondary Live Volume array. Instead, these paths would be reserved for use as failover paths. Examples of these types of MPIO policies are **Failover Only** or **Fixed**. Use cases include asynchronous replication link slowness or a QoS node that adds too much latency to proxied traffic.

A Round Robin MPIO policy may also be used with Live Volume. There may be slight deviations based on the storage host, but in general, with the ALUA support added in SCOS 7.3, Round Robin utilizes all available optimal paths to a device. MPIO paths leading to the primary Live Volume are advertised by the SC Series array as optimal. In the event optimal paths are not available, Round Robin will then utilize non-optimal paths that are available. MPIO paths leading to the secondary Live Volume are advertised by the SC Series array as non-optimal.

Standalone servers or clustered servers accessing shared storage may use uniform storage presentation. Uniform storage presentation provides host to Live Volume storage paths through both arrays. With the Live Volume ALUA feature enabled, a Round Robin path selection policy can quickly and easily be configured with uniform storage presentation. With the ALUA intelligence built into both the storage host and the arrays, optimal MPIO paths will be used for I/O and the storage fabric will be both well utilized and well balanced.

For non-vSphere or Microsoft storage hosts in a uniform Live Volume configuration, all MPIO paths will be reported as optimal. When using a Round Robin path selection policy, half of the I/O will go through the primary Live Volume and the other half with be proxied through the replication link through the secondary Live Volume. This may or may not be a good design choice. Also, the automatic role swap feature will not be able to make an accurate determination of where the primary Live Volume should be, and the feature will be ineffective if enabled.

Clustered servers accessing shared storage may also use non-uniform storage presentation. Non-uniform means that each cluster node will access a Live Volume through one array or the other, but not both. Non-uniform typically applies to a stretched cluster configuration where each node in the cluster accesses the Live Volume through paths that are local in fabric proximity only. Each cluster node would have read/write access to either the primary or the secondary Live Volume, but not both simultaneously. For the cluster nodes which have access to the primary Live Volume, their front-end I/O will remain local in proximity. For the cluster nodes which have access to the secondary Live Volume, their front-end I/O will be proxied to the primary Live Volume through the replication link. Implementing Round Robin with non-uniform presentation is typically preferred to provide automated port and fabric balancing, but fixed paths may also be used. Automatic role swap would be preferred with non-uniform storage presentation so that a role swap will automatically follow the vMotion of virtual machines between sites.

Regardless of storage presentation, MPIO path selection, and role swap policies, synchronous replication latency between arrays will impact applications. Additional information on configuring Live Volume MPIO can be found in each of the application-specific sections of this document, such as VMware vSphere (section 8), Microsoft Windows/Hyper-V (section 9), and Linux/Unix (section 10).

8 VMware vSphere and Live Volume

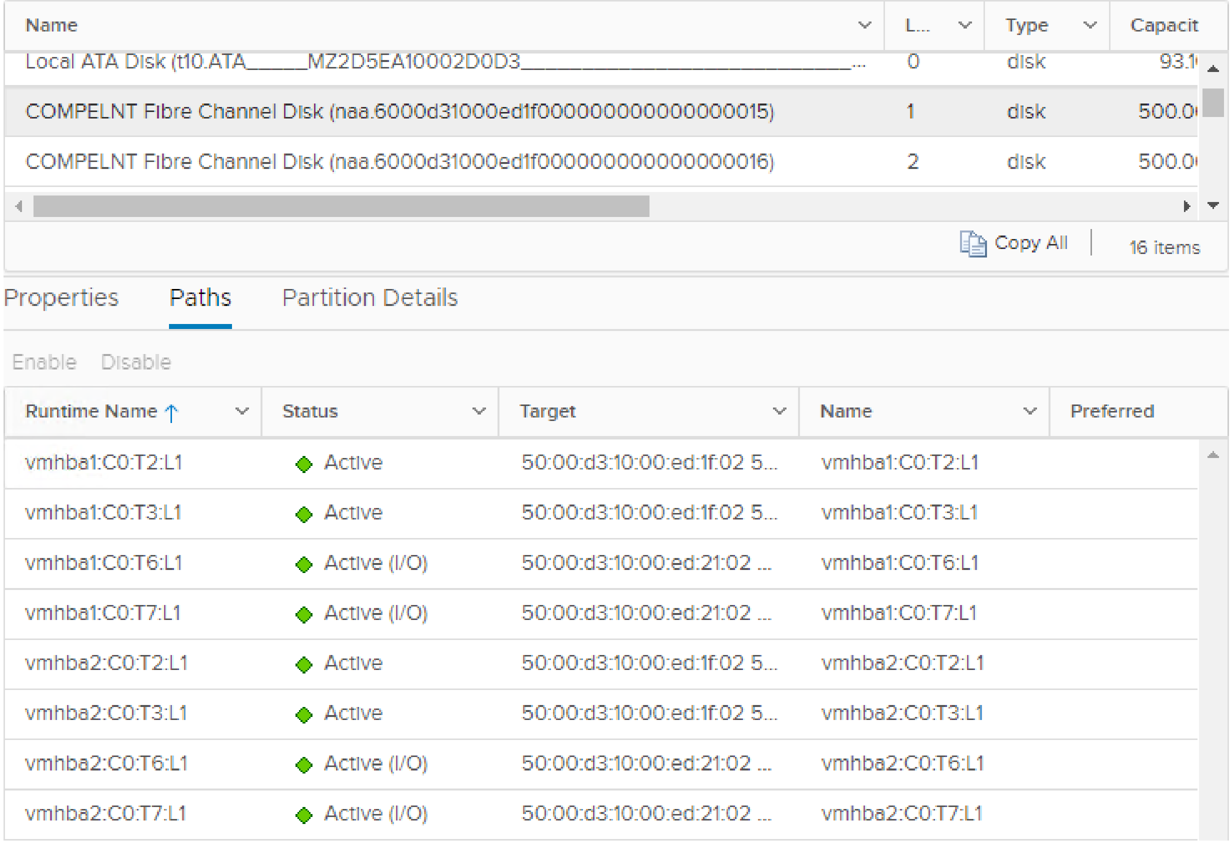
When vSphere and Live Volume combine, they can provide VMware-certified, large-scale application and service mobility, high availability, planned maintenance, resource balancing, disaster avoidance, and disaster recovery options for virtual environments.

8.1 Path Selection Policies (PSP)

vSphere ships with three MPIO path selection policies (PSP): **Fixed**, **Round Robin,** and **Most Recently Used** (MRU is not tested and should not be used with SC Series storage). The best path selection policy to choose with Live Volume depends on uniform or non-uniform storage presentation, available ALUA support, replication type, latency between sites or arrays, and customer preference. Round Robin is largely the easiest PSP to configure and provides both optimal I/O performance and balance of the storage fabric in uniform storage presentations with ALUA support or non-uniform storage presentation with or without ALUA support.

8.2 Round Robin with Live Volume ALUA

Figure 42 depicts a Round Robin policy with a uniformly presented Live Volume between two SC Series arrays with the ALUA feature (introduced in SCOS 7.3). Read and write I/O will follow the Round Robin policy, taking optimal paths directly to the primary Live Volume, shown as Active (I/O), in a uniform Live Volume storage presentation. Non-optimal paths lead to the secondary Live Volume and will be reserved for use in the event all optimal paths to the primary Live Volume become unavailable. In the event of a Live Volume role swap, the non-optimal paths reported by the SC Series array become optimal, and the optimal paths become non-optimal.



Name	L...	Type	Capacit
Local ATA Disk (t10.ATA_____MZ2D5EA10002D0D3____________________________...	0	disk	93.1
COMPELNT Fibre Channel Disk (naa.6000d31000ed1f000000000000000015)	1	disk	500.0
COMPELNT Fibre Channel Disk (naa.6000d31000ed1f000000000000000016)	2	disk	500.0

Copy All | 16 items

Runtime Name ↑	Status	Target	Name	Preferred
vmhba1:C0:T2:L1	◆ Active	50:00:d3:10:00:ed:1f:02 5...	vmhba1:C0:T2:L1	
vmhba1:C0:T3:L1	◆ Active	50:00:d3:10:00:ed:1f:02 5...	vmhba1:C0:T3:L1	
vmhba1:C0:T6:L1	◆ Active (I/O)	50:00:d3:10:00:ed:21:02 ...	vmhba1:C0:T6:L1	
vmhba1:C0:T7:L1	◆ Active (I/O)	50:00:d3:10:00:ed:21:02 ...	vmhba1:C0:T7:L1	
vmhba2:C0:T2:L1	◆ Active	50:00:d3:10:00:ed:1f:02 5...	vmhba2:C0:T2:L1	
vmhba2:C0:T3:L1	◆ Active	50:00:d3:10:00:ed:1f:02 5...	vmhba2:C0:T3:L1	
vmhba2:C0:T6:L1	◆ Active (I/O)	50:00:d3:10:00:ed:21:02 ...	vmhba2:C0:T6:L1	
vmhba2:C0:T7:L1	◆ Active (I/O)	50:00:d3:10:00:ed:21:02 ...	vmhba2:C0:T7:L1	

Figure 42 Round Robin policy

Note: ALUA information used by the Round Robin PSP for a device can also be viewed using esxcli as shown in the following example. **TPG_state** identifies the active/optimal and active/non-optimal ALUA state for each target port group. **Working Paths** identifies each active/optimal path for Round Robin as derived from the target port groups.

```
[root@s1212:~] esxcli storage nmp device list -d
naa.6000d31000ed1f000000000000000015
naa.6000d31000ed1f000000000000000015
   Device Display Name: COMPELNT Fibre Channel Disk
(naa.6000d31000ed1f000000000000000015)
   Storage Array Type: VMW_SATP_ALUA
   Storage Array Type Device Config: {implicit_support=on; explicit_support=off;
explicit_allow=on; alua_followover=on; action_OnRetryErrors=off;
{TPG_id=61480,TPG_state=ANO}{TPG_id=61731,TPG_state=AO}{TPG_id=61735,TPG_state=A
O}{TPG_id=61732,TPG_state=AO}{TPG_id=61475,TPG_state=ANO}{TPG_id=61736,TPG_state
=AO}{TPG_id=61479,TPG_state=ANO}{TPG_id=61476,TPG_state=ANO}}
   Path Selection Policy: VMW_PSP_RR
   Path Selection Policy Device Config:
{policy=rr,iops=1000,bytes=10485760,useANO=0; lastPathIndex=6:
NumIOsPending=0,numBytesPending=0}
   Path Selection Policy Device Custom Config:
   Working Paths: vmhba3:C0:T15:L1, vmhba2:C0:T15:L1, vmhba3:C0:T14:L1,
vmhba2:C0:T14:L1
   Is USB: false
```

If a Live Volume role swap occurs, the SC Series array is designed to report the ALUA path state changes to the vSphere host using the following process (according to the T10 SCSI-3 specification SPC-3):

1. A Live Volume role swap occurs between optimal and non-optimal paths.
2. The vSphere hosts send Round Robin I/O to what is now the secondary Live Volume through non-optimal paths.
3. The SC Series array fails the I/O with a Unit Attention Check Condition.
4. The vSphere host requests Report Target Port Groups.
5. The SC Series array responds with new ALUA state changes.
6. vSphere begins Round Robin I/O over new optimal paths.

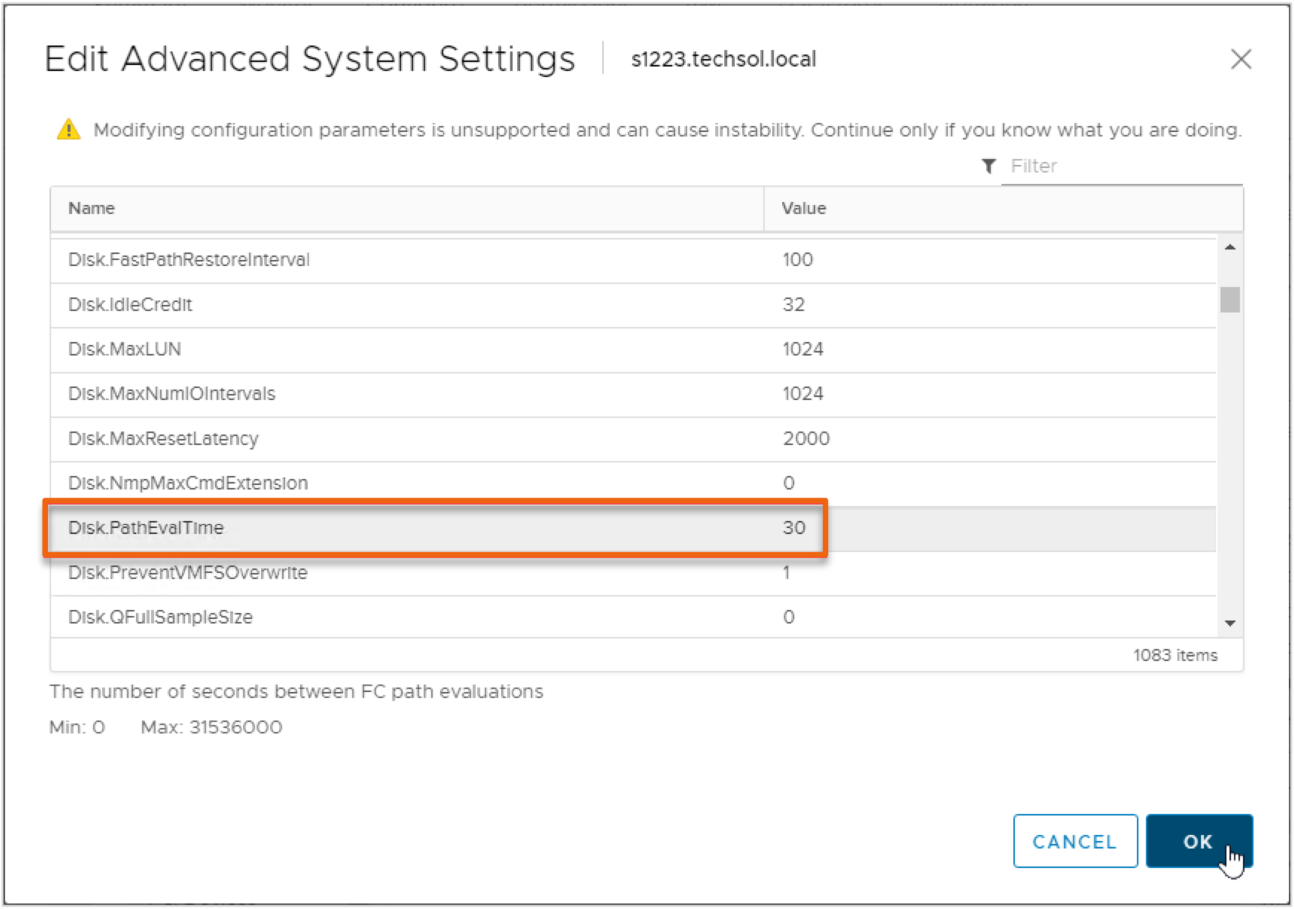
Note: The **Unit Attention Check Condition** can be observed in **/var/log/vmkernel.log** in the following example. For more information, see the VMware KB article, [Interpreting SCSI sense codes in VMware ESXi and ESX (289902).]

```
2018-02-28T16:59:02.589Z cpu18:66287)NMP: nmp_ThrottleLogForDevice:3617: Cmd
0x28 (0x439500e6bdc0, 111979) to dev "naa.6000d31000ed1f000000000000000015" on
path "vmhba3:C0:T15:L1" Failed: H:0x0 D:0x2 P:0x0 Valid sense data: 0x6 0x2a
0x6. Act:FAILOVER
```

During extensive testing, it was discovered that vSphere did not consistently or reliably begin using the new optimal primary Live Volume paths immediately after a role swap as designed. Instead, up to five minutes elapsed before vSphere recognized the ALUA path state change. This means that vSphere may continue to follow the Round Robin policy over the non-optimal paths to the secondary Live Volume for up to five minutes. Dell Technologies is working with VMware to understand this behavior.

For customers concerned about this behavior occurring in their environments, there are two workarounds:

- After the Live Volume role swap, perform a vSphere storage rescan.
- Reduce the vSphere host advanced setting **Disk.PathEvalTime** from the default of 300 seconds down to an acceptable automatic storage rescan interval. This would need to be performed on each vSphere host the Live Volume is mapped to.



Edit Advanced System Settings | s1223.techsol.local

⚠ Modifying configuration parameters is unsupported and can cause instability. Continue only if you know what you are doing.

Name	Value
Disk.FastPathRestoreInterval	100
Disk.IdleCredit	32
Disk.MaxLUN	1024
Disk.MaxNumIOIntervals	1024
Disk.MaxResetLatency	2000
Disk.NmpMaxCmdExtension	0
Disk.PathEvalTime	30
Disk.PreventVMFSOverwrite	1
Disk.QFullSampleSize	0

1083 items

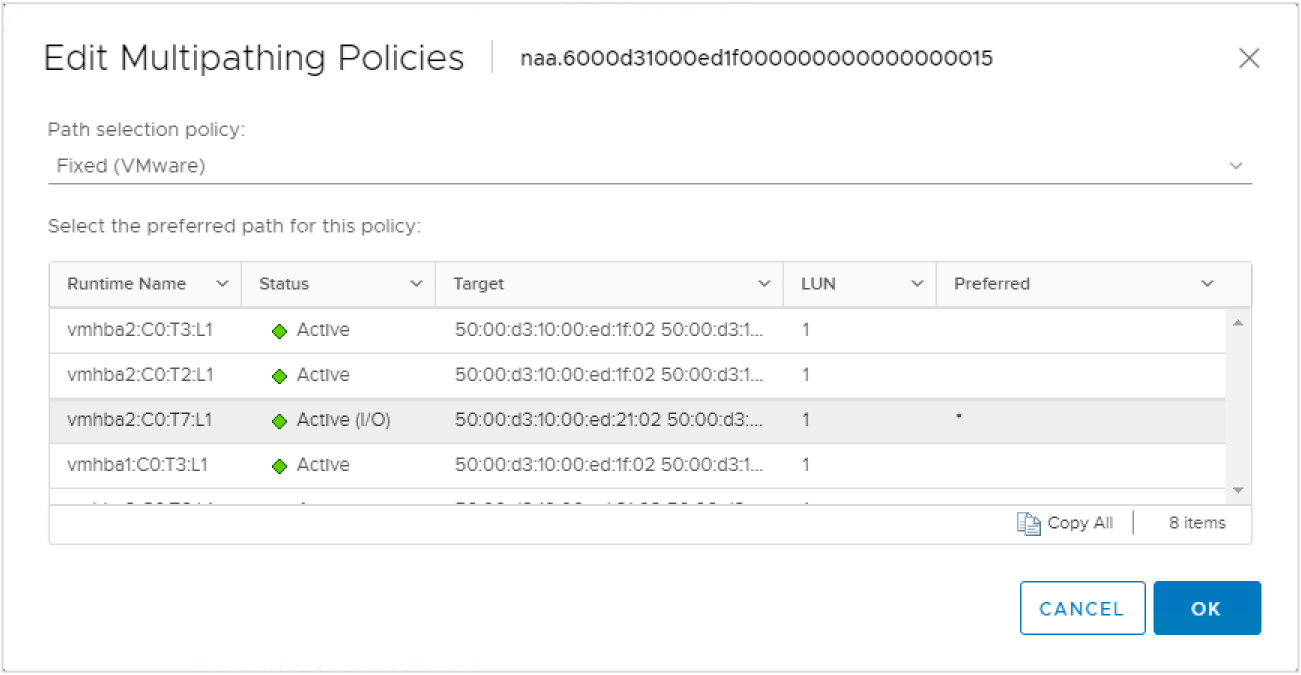
The number of seconds between FC path evaluations

Min: 0 Max: 31536000

Figure 43 Example: Reducing the Disk.PathEvalTime setting to 30 seconds on a vSphere host

8.3 Fixed

The Fixed PSP may be desirable when a preferred path on the storage fabric should be used. The Fixed PSP may also be useful in a uniform Live Volume storage presentation, if the ALUA feature (added in SCOS 7.3) is not yet available, in order to avoid sending read and write I/O down a non-optimal path to the secondary Live Volume. As shown in Figure 44, the MPIO policy on the vSphere host should be set to **Fixed** with the preferred path leading to the primary Live Volume. Using the Fixed PSP generally requires more administrative effort to implement, maintain, and document.



Edit Multipathing Policies | naa.6000d31000ed1f000000000000000015

Path selection policy:
Fixed (VMware)

Select the preferred path for this policy:

Runtime Name	Status	Target	LUN	Preferred
vmhba2:C0:T3:L1	Active	50:00:d3:10:00:ed:1f:02 50:00:d3:1...	1	
vmhba2:C0:T2:L1	Active	50:00:d3:10:00:ed:1f:02 50:00:d3:1...	1	
vmhba2:C0:T7:L1	Active (I/O)	50:00:d3:10:00:ed:21:02 50:00:d3:...	1	*
vmhba1:C0:T3:L1	Active	50:00:d3:10:00:ed:1f:02 50:00:d3:1...	1	

Figure 44 Fixed policy

8.4 Single-site MPIO configuration

In a single-site or uniform configuration, vSphere hosts may be zoned to both arrays. If a Live Volume is mapped over both arrays to the vSphere hosts, the volume can participate in an MPIO configuration involving both arrays. In a Live Volume configuration, the optimal I/O path is through the primary Live Volume. In this scenario, using the vSphere Round Robin MPIO policy in conjunction with the Live Volume ALUA feature ensures I/O traffic goes through the primary Live Volume array. This is a preferred configuration because it requires minimal administrative effort and yields a well-balanced fabric.

Alternatively, the vSphere Fixed MPIO policy with preferred path can be used to ensure front-end I/O traffic is going through the primary Live Volume array. In the event a Live Volume role swap occurs, the preferred path will need to be updated on each vSphere host to point to an optimal primary Live Volume path. This is where additional administrative effort is involved to maintain a well-balanced fabric.

As depicted in Figure 45, a Live Volume replication exists between SC Series A and SC Series B. Two vSphere hosts are mapped to the Live Volume on each array. The Primary Live Volume is located on SC Series A, and the Fixed preferred path (Figure 44) on each vSphere host is configured to use a path to SC Series A as the preferred path.

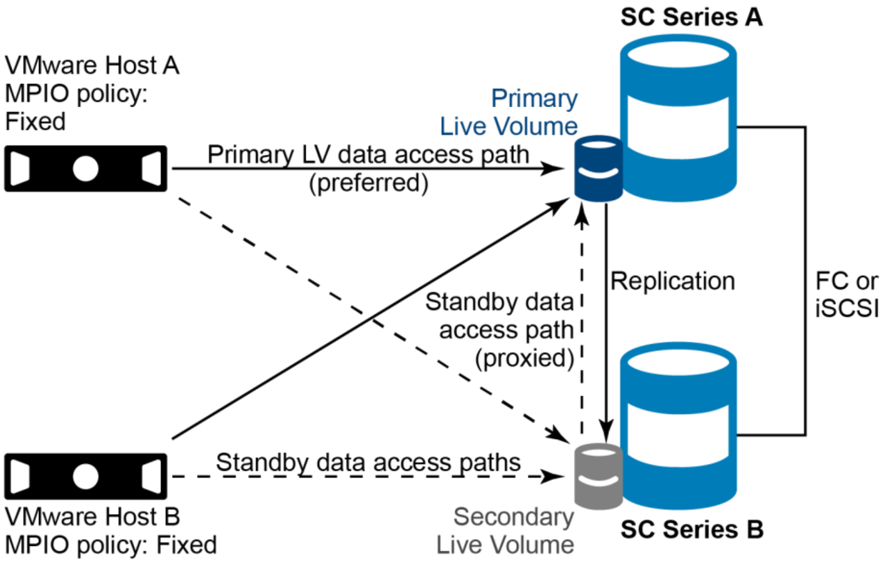


Figure 45 Uniform Live Volume replication

If planned downtime will impact SC Series A, the preferred path for the vSphere hosts could be configured for SC Series B. When the Live Volume is configured for automatic role swap, this change in preferred paths will trigger the Live Volume to swap roles making SC Series B the Primary Live Volume controller, allowing SC Series A to be taken offline without a disruption to virtual machines on that Live Volume.

8.5 Multi-site MPIO configuration

In a multi-site or non-uniform stretched cluster configuration, each vSphere host is zoned and mapped only to its local corresponding array (see Figure 46).

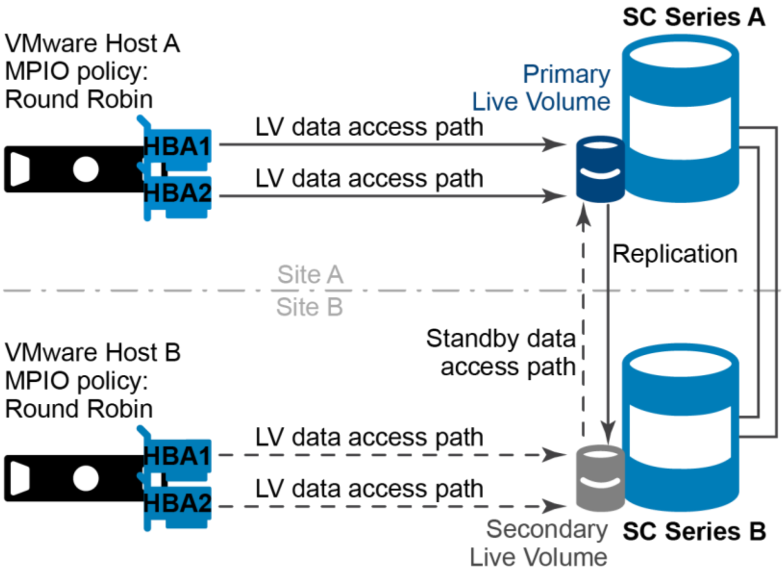


Figure 46 Non-uniform multi-site MPIO configuration

In this configuration, the MPIO policy for the primary Live Volume can be configured as either Round Robin (preferred) or Fixed. Enabling Live Volume automatic role swap would be optimal in this configuration where vMotion is used to migrate virtual machines between sites (for example, from Site A to Site B). After the vMotion occurs, read and write I/O stemming from VMware Host B to the secondary Live Volume is proxied to the Primary Live Volume controller through the asynchronous or synchronous replication link(s) between the arrays. Automatic role swap allows SC Series storage to optimize the I/O after vMotion so that all or the majority is flowing through the primary Live Volume.

Multiple sites and stretched clusters may also be configured with uniform storage presentation. For more information on vMSC storage presentation, see section 8.9.

8.6 VMware vMotion and Live Volume

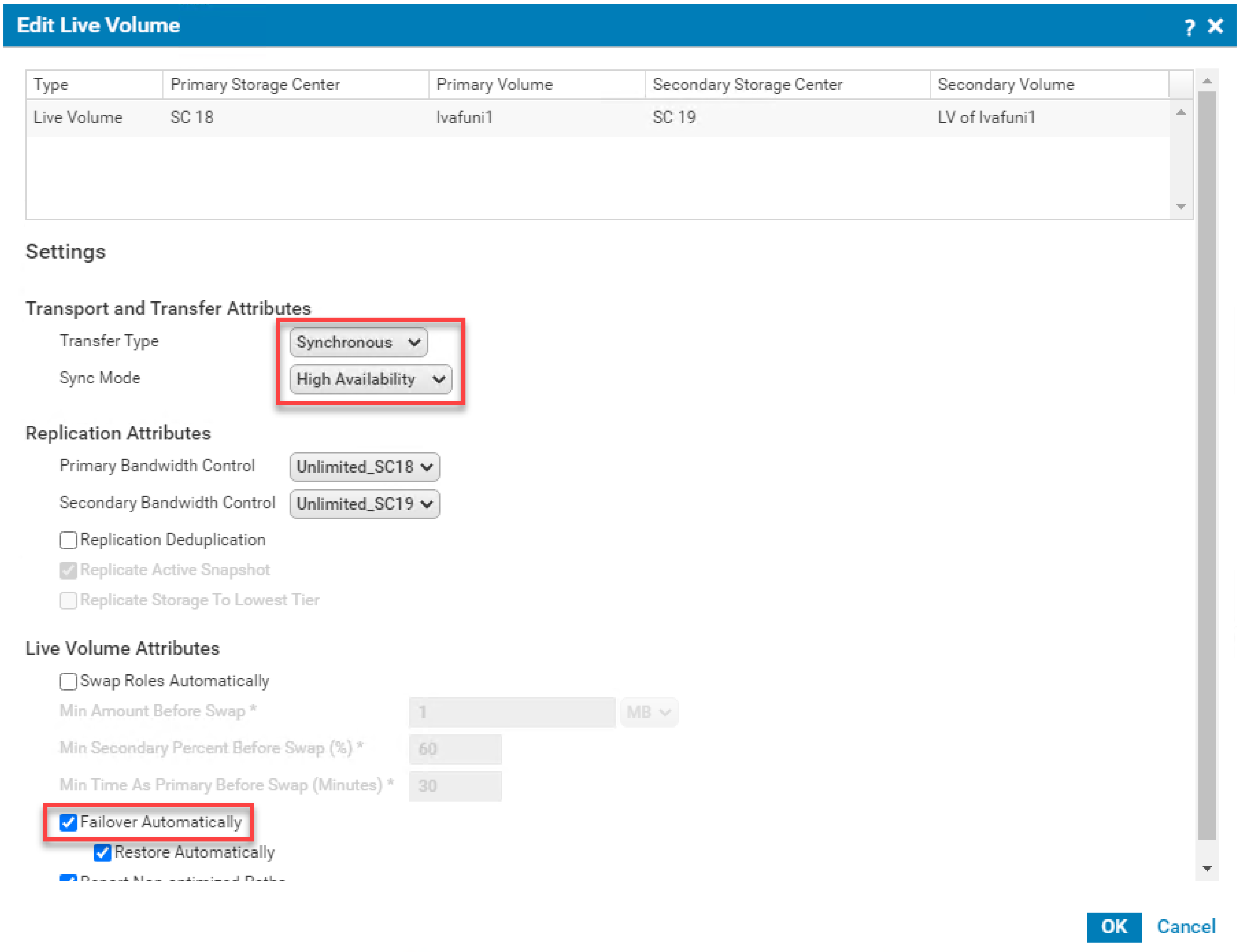
In a non-uniform storage presentation model, one method of controlling the location of the primary Live Volume is to use vMotion and configure Live Volume automatic role swap (see Figure 46). vSphere Host A is mapped to SC Series A and vSphere Host B is mapped to SC Series B. When a virtual machine running on a Live Volume is migrated from Host A to Host B, Live Volume with automatic role swap observes that the storage access has shifted from SC Series A to SC Series B. The SC Series array automatically swaps the Secondary Live Volume to become the Primary Live Volume. Once this occurs, the virtual machine disk I/O traverses a local path to the Primary Live Volume on SC Series B (using the Fixed or Round Robin MPIO policy) instead of going through the Secondary Live Volume proxy across the replication link. The result evades an inevitably higher cost in terms of increased latency. For stretched clusters or data centers, consider the vMotion and Metro vMotion latency requirements between hosts. vMotion requires a round-trip latency of 5 ms or less between hosts on the vMotion network. vSphere Metro Storage Cluster boosts the allowable round-trip latency from 5 ms to 10 ms on the vMotion network between sites.

8.7 vSphere Metro Storage Cluster

vSphere Metro Storage Cluster (vMSC) is a specific VMware-certified design and is an implementation of vSphere, compute, storage, and network infrastructure. The design is typically a stretched cluster configuration over varying distances to provide high availability for virtualized workloads. This is achieved through continuous availability of compute and storage resources provided by a combination of hardware redundancy and automatic failover capabilities built into the vSphere hypervisor and the SC Series Live Volume architecture. With the configuration of the Live Volume automatic failover feature, and by meeting other solution requirements, SC Series storage is certified by VMware in supporting vSphere Metro Storage Cluster in uniform, non-uniform, Fibre Channel, and iSCSI designs.

8.8 Live Volume automatic failover

Configuring Live Volume for synchronous high availability replication and automatic failover (Figure 47) is a key requirement for vMetro Storage Cluster deployments. Live Volume and replication may be configured on a per-volume basis using the SC Series vSphere web client plug-in or Unisphere Central for SC Series. The Failover Automatically feature for Live Volume is configured using DSM. Live Volume automatic failover is supported with VMware vSphere 5.5 or newer VMFS datastores and virtual mode RDMs, with support for physical mode RDMs added with the release of SCOS 7.1.



Edit Live Volume

Type	Primary Storage Center	Primary Volume	Secondary Storage Center	Secondary Volume
Live Volume	SC 18	lvafuni1	SC 19	LV of lvafuni1

Settings

Transport and Transfer Attributes

Transfer Type: Synchronous

Sync Mode: High Availability

Replication Attributes

Primary Bandwidth Control: Unlimited_SC18

Secondary Bandwidth Control: Unlimited_SC19

☐ Replication Deduplication

☑ Replicate Active Snapshot

☐ Replicate Storage To Lowest Tier

Live Volume Attributes

☐ Swap Roles Automatically

Min Amount Before Swap *: 1 MB

Min Secondary Percent Before Swap (%) *: 60

Min Time As Primary Before Swap (Minutes) *: 30

☑ Failover Automatically

☑ Restore Automatically

☑ Report Non-optimized Paths

Figure 47 Live Volume configured with Synchronous, High Availability, and Failover Automatically enabled

8.9 vMSC storage presentation

vSphere Metro Storage Cluster supports uniform or non-uniform storage presentation and fabric designs. Within the vMSC entity, one presentation model should be implemented consistently for all vSphere hosts in the stretched cluster. Mixing storage presentation models within a stretched cluster is not recommended. It may work but it has not been formally or thoroughly tested.

8.9.1 vMSC uniform storage presentation

Uniform presentation (Figure 48) tends to be a more common design, which provides host-to-Live-Volume storage paths through both arrays. This means that half of the I/O will go through the primary Live Volume and the other half with be proxied through the replication link through the secondary Live Volume. Uniform presentation helps provide a better level of uptime for virtual machines if Live Volume automatic failover occurs because of an unplanned storage or fabric outage. Automatic role swap may or may not disabled when using the Round Robin PSP in conjunction with uniform storage presentation.

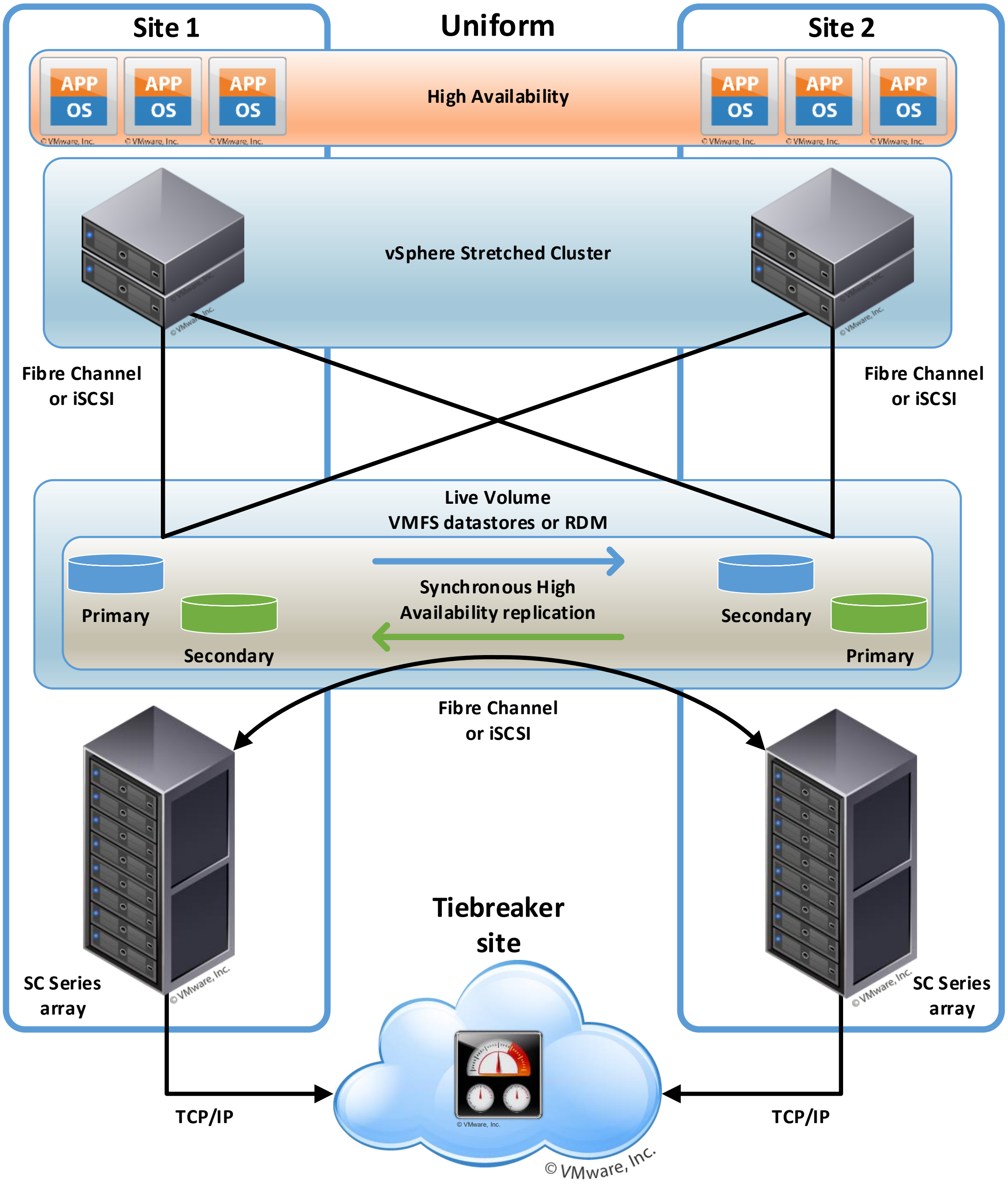


Figure 48 vMSC uniform storage presentation

8.9.2 vMSC non-uniform storage presentation

Non-uniform means that each vSphere Metro Storage Cluster host will access a Live Volume through one array or the other, but not both. Each cluster node has read/write access to either the primary or the secondary Live Volume, but not both simultaneously. For the cluster nodes with access to the primary Live Volume, their front-end I/O remains local in proximity. For the cluster nodes with access to the secondary Live Volume, their front-end I/O is proxied to the primary Live Volume using the replication link. Implementing Round Robin with non-uniform presentation is typically preferred to provide automated port and fabric balance but fixed paths may also be used. Automatic role swap would be preferred with non-uniform storage presentation so that a role swap will automatically follow the vMotion of virtual machines between sites.

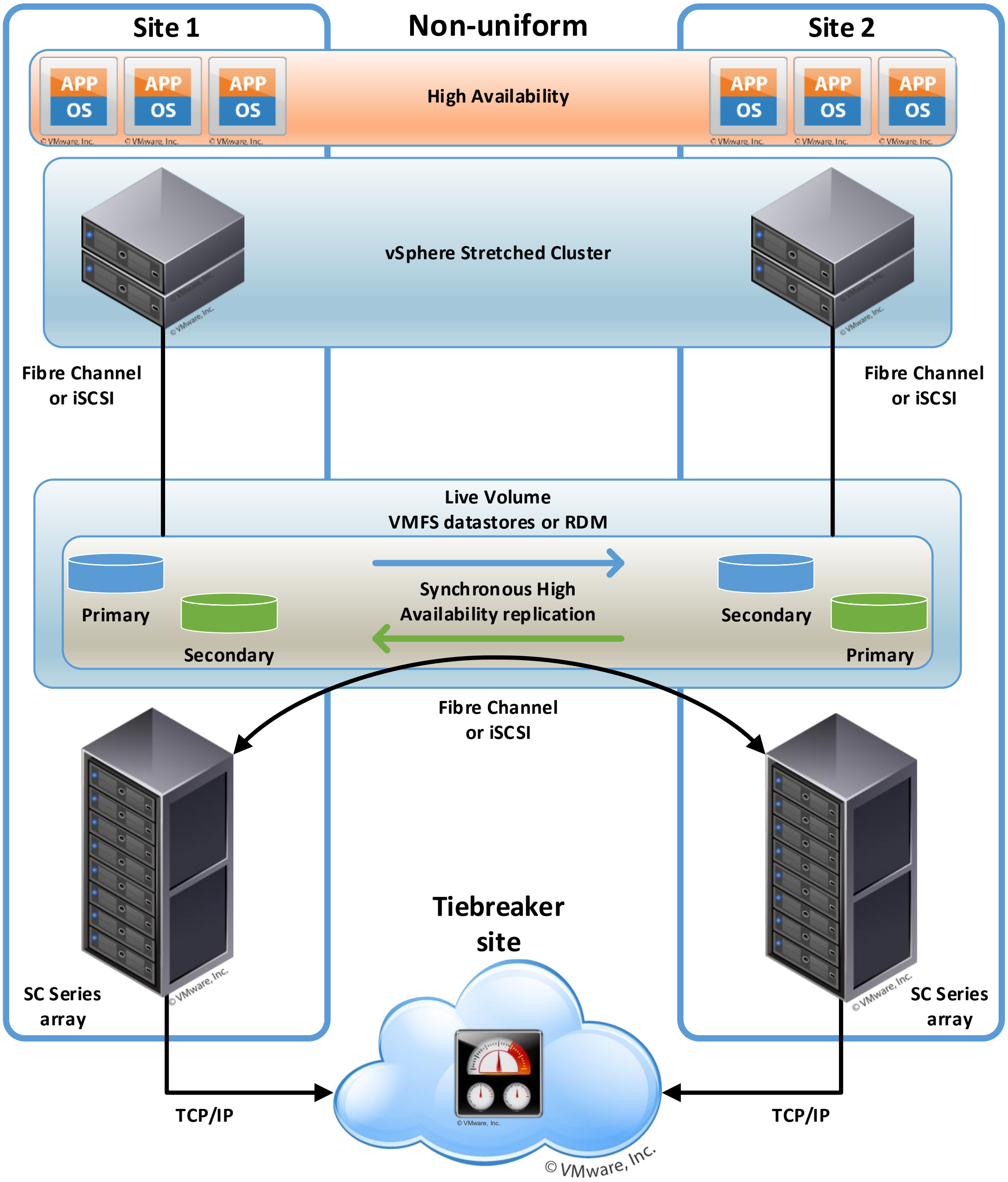


Figure 49 vMSC non-uniform storage presentation

8.10 Tiebreaker service

A tiebreaker service is built into the Dell Storage Manager Data Collector as well as the Remote Data Collector, and acts as a quorum to facilitate Live Volume automatic failover. It also plays an important role in preventing split-brain conditions should a network or fabric partition between arrays occur. The tiebreaker should be located at a site physically independent of arrays participating in a Metro Cluster. This may be in a customer-owned data center or public cloud. Although tiebreaker availability is not required for Live Volume I/O during healthy operating conditions, the tiebreaker service is required to act on unplanned Live Volume component outages (typically, the result is automatic failover but this is not always the case) and network latency to the tiebreaker from each array must not exceed 200 ms RTT.

8.11 Common automatic failover scenarios

The following sections outline failure scenarios and the resulting Live Volume automatic failover behavior. These are scenarios commonly asked about by customers, not necessarily scenarios that are likely to commonly occur.

8.11.1 Primary Live Volume array failure

If an unplanned event impacts an SC Series array that is hosting a primary Live Volume, Live Volume availability is automatically failed over to the surviving array.

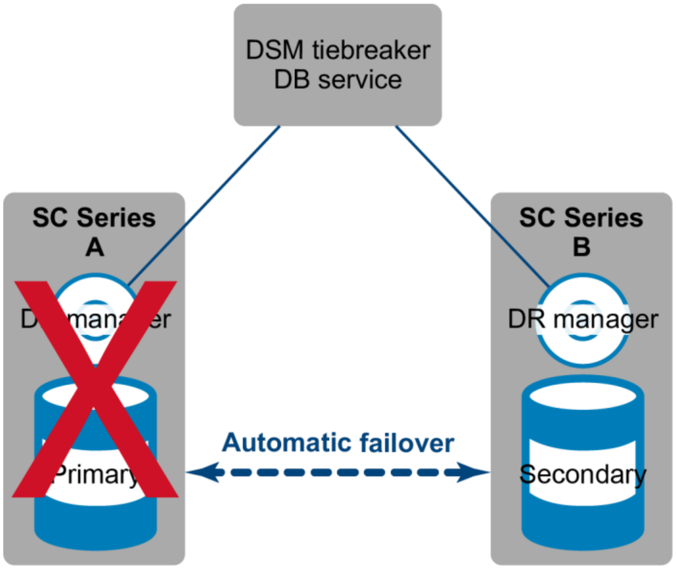


Figure 50 Primary Live Volume failure

8.11.2 Secondary Live Volume array failure

If an unplanned event impacts an SC Series array hosting a secondary Live Volume, the primary Live Volume remains available on the surviving array.

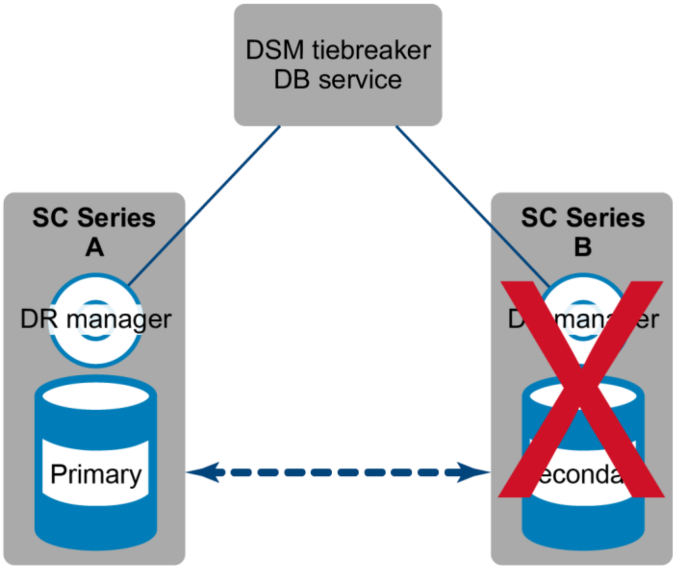


Figure 51 Secondary Live Volume failure

8.11.3 Replication network partition

If an unplanned event impacts the replication link between SC Series arrays, the primary Live Volume will continue to remain available serving I/O and no automatic failover will occur. The secondary Live Volume will be unable to proxy I/O requests to the primary Live Volume while the replication link is down.

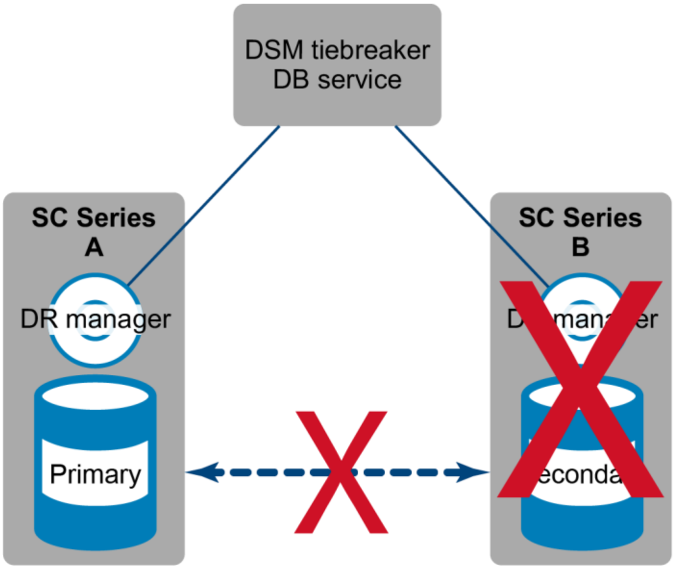


Figure 52 Replication link failure

8.11.4 SC Series back-end outage

If an unplanned event impacts primary Live Volume back-end SC Series components (such as the loss of several drives or a drive shelf), the primary Live Volume will automatically fail over to the surviving array. Both arrays will continue to service I/O requests from the primary Live Volume locally and remotely through the replication link.

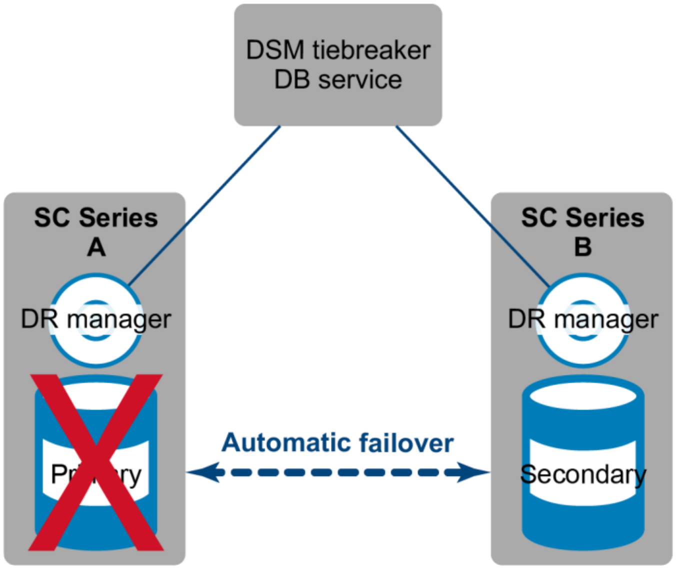


Figure 53 Primary back-end failure

8.11.5 Tiebreaker failure

If an unplanned event impacts the availability of the tiebreaker service on the DSM server, both SC Series arrays will continue to service I/O requests but no automatic failover can occur during this time.

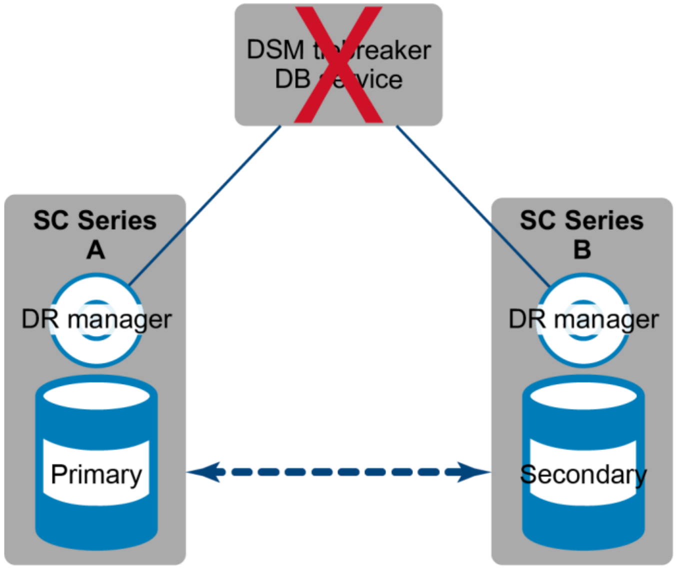


Figure 54 Tiebreaker failure

8.11.6 Tiebreaker service link failure

Similar to the previous example, if either SC Series array loses network connectivity to the tiebreaker service on the DSM server, both arrays will continue to service I/O requests but no automatic failover can occur during this time.

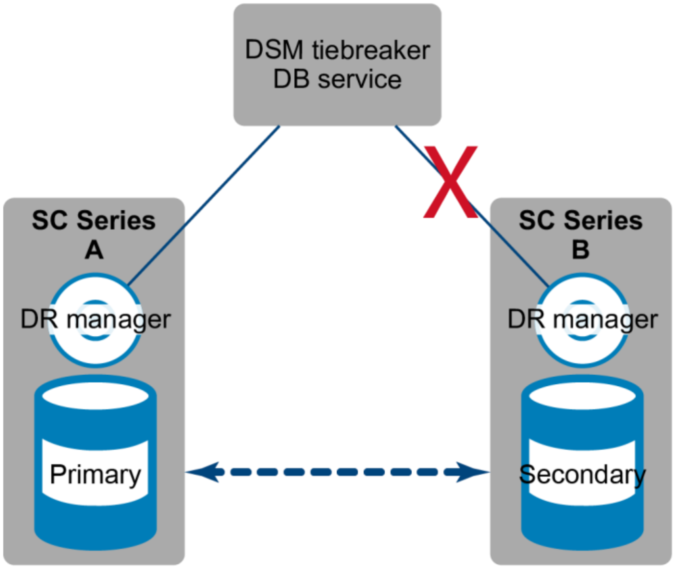


Figure 55 Tiebreaker link failure

8.12 Detailed failure scenarios

The following table outlines tested design and component failure scenarios with Live Volume automatic failover enabled with vSphere HA.

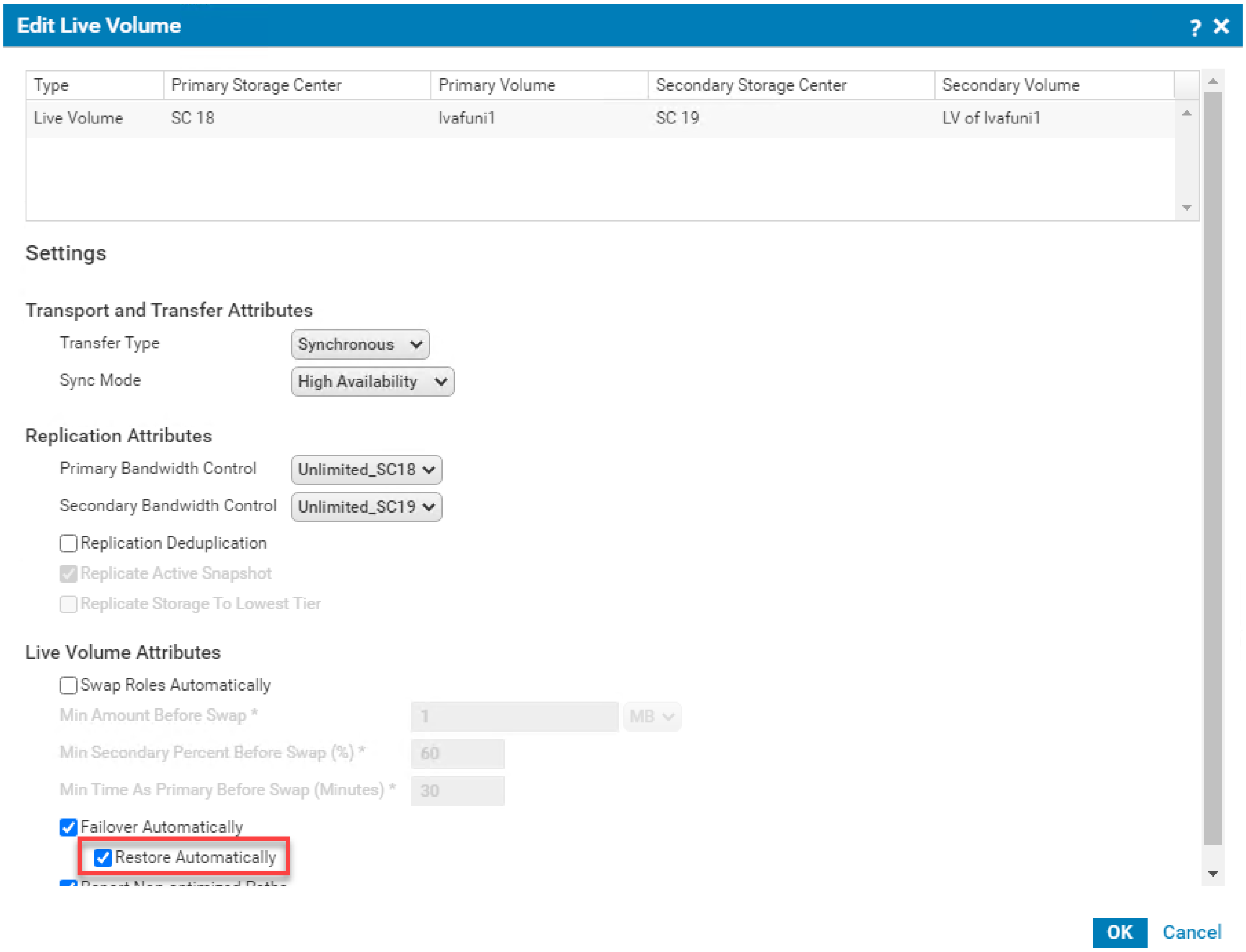
Event scenario	Live Volume behavior	vSphere HA behavior
Uniform: Complete site outage takes down primary Live Volumes	Primary Live Volumes automatically recovered at remote site	vSphere HA restarts impacted VMs at remote site
Uniform: Complete site outage takes down secondary Live Volumes	Primary Live Volumes remain available at remote site	vSphere HA restarts impacted VMs at remote site
Non-uniform: Complete site outage takes down primary Live Volumes	Primary Live Volumes automatically recovered at remote site	vSphere HA restarts impacted VMs at remote site
Non-uniform: Complete site outage takes down secondary Live Volumes	Primary Live Volumes remain available at remote site	vSphere HA restarts impacted VMs at remote site
Uniform: SC Series controller-pair outage takes down primary Live Volumes	Primary Live Volumes automatically recovered at remote site	None – VMs remain running at both sites
Uniform: SC Series controller-pair outage takes down secondary Live Volumes	Primary Live Volumes remain available at remote site	None – VMs remain running at both sites

Event scenario	Live Volume behavior	vSphere HA behavior
Non-uniform: SC Series controller-pair outage takes down primary Live Volumes	Primary Live Volumes automatically recovered at remote site	vSphere HA restarts impacted VMs at remote site
Non-uniform: SC Series controller-pair outage takes down secondary Live Volumes	Primary Live Volumes remain available at remote site	vSphere HA restarts impacted VMs at remote site
Uniform: SC Series back-end outage (such as loss of drive enclosure or multiple drives) takes down primary Live Volumes	Primary Live Volumes automatically recovered at remote site SC Series continues to provide Live Volume access from both arrays	None – VMs remain running at both sites
Uniform: SC Series back-end outage (such as loss of drive enclosure or multiple drives) takes down secondary Live Volumes	Primary Live Volumes remain available at remote site SC Series continues to provide Live Volume access from both arrays	None – VMs remain running at both sites
Non-uniform: SC Series-back end outage (such as loss of drive enclosure or multiple drives) takes down primary Live Volumes	Primary Live Volumes automatically recovered at remote site SC Series continues to provide Live Volume access from both arrays	None – VMs remain running at both sites
Non-uniform: SC Series back-end outage (such as loss of drive enclosure or multiple drives) takes down secondary Live Volumes	Primary Live Volumes remain available at remote site SC Series continues to provide Live Volume access from both arrays	None – VMs remain running at both sites
Uniform: Replication link failure between sites	No automatic failover Primary Live Volumes remain available Secondary Live Volumes go offline	None – VMs remain running at both sites
Non-uniform: Replication link failure between sites	No auto failover Primary Live Volumes remain available Secondary Live Volumes go offline	VMs which were running on primary Live Volumes: None – VMs remain running VMs which were running on secondary Live Volumes: vSphere HA restarts VMs at remote site

Event scenario	Live Volume behavior	vSphere HA behavior
Tiebreaker service failure	No automatic failover Primary Live Volumes remain available Secondary Live Volumes remain available	None – VMs remain running at both sites
Tiebreaker service network isolated from either or both array sites	No auto failover Primary Live Volumes remain available Secondary Live Volumes remain available	None – VMs remain running at both sites

8.13 Live Volume automatic restore

Live Volumes configured for automatic failover are also be configured for automatic restore by default (Figure 56). If Live Volume Automatic Failover has occurred and the impacted array and data center infrastructure is subsequently recovered and brought back online, the Restore Automatically feature will repair Live Volumes by replicating changed data back to the impacted site (leveraging the built-in minimal recopy feature) and then bring the failed Live Volume back online as a secondary. The Restore Automatically feature is configured on a per-Live-Volume basis and it is recommended to leave this enabled for the purposes of automation, consistency, efficiency, and high availability of consistent data.



Edit Live Volume

Type	Primary Storage Center	Primary Volume	Secondary Storage Center	Secondary Volume
Live Volume	SC 18	lvafuni1	SC 19	LV of lvafuni1

Settings

Transport and Transfer Attributes

Transfer Type: Synchronous

Sync Mode: High Availability

Replication Attributes

Primary Bandwidth Control: Unlimited_SC18

Secondary Bandwidth Control: Unlimited_SC19

☐ Replication Deduplication

☑ Replicate Active Snapshot

☐ Replicate Storage To Lowest Tier

Live Volume Attributes

☐ Swap Roles Automatically

Min Amount Before Swap *: 1 MB

Min Secondary Percent Before Swap (%) *: 60

Min Time As Primary Before Swap (Minutes) *: 30

☑ Failover Automatically

☑ Restore Automatically

☑ Report Non-optimized Paths

Figure 56 Live Volume configured with Restore Automatically enabled

8.14 VMware DRS/HA and Live Volume

VMware Distributed Resource Scheduler (DRS) is a cluster-centric configuration that uses VMware vSphere vMotion® to automatically move virtual-machine compute resources to other nodes in a cluster. This is performed without local, metro, or stretched-site awareness. In addition, vSphere is unaware of storage virtualization that occurs in Live Volume. When Live Volume is configured with a vSphere stretched cluster, it is a best practice to keep virtual machines running at the same site as their primary Live Volumes. Additionally, it is recommended to keep virtual machines that share a common Live Volume datastore together at the same site. This ensures that compute and storage resources remain local to the vSphere host running the virtual machine(s). If DRS is activated on a vSphere cluster with nodes in each site, DRS could automatically move some of the virtual machines running on a Live Volume datastore to a host that resides in the other data center.

In vSphere 4.1 and later, DRS host groups and VM groups can be used to benefit a vSphere Metro Storage Cluster environment.

- **VM groups:** Virtual machines that share a common Live Volume datastore can be placed into VM groups. Movement of virtual machines and management of their respective Live Volume datastore, can then be performed at a containerized-group level rather than at an individual virtual-machine level.

- **Host groups:** Hosts that share a common site can be placed into host groups. Once the host groups are configured, they can represent locality for the primary Live Volume.

VM groups can be assigned to host groups using the DRS Groups Manager. This will ensure all virtual machines that share a common Live Volume datastore are consistently running from the same datastore. The virtual machines can be vMotioned as a group from one site to another. After a polling threshold is met, SC Series storage can perform an automatic role swap of the primary Live Volume datastore to the site where the VMs were migrated. The infrastructure can also be designed with separate DRS-enabled clusters existing at both sites, keeping automatic migration of virtual machines within the respective site where the primary Live Volume resides. In the event of a Live Volume role swap, all virtual machines associated with the Live Volume can be vMotioned from the site A cluster to the site B cluster.

vSphere High Availability (HA) is also a cluster-centric configuration. In the event of a host or storage failure, HA will attempt to restart virtual machines on a host candidate within the same cluster that may be local or stretched in a vMSC deployment. In a non-uniform storage configuration, if an outage impacts primary Live Volume availability and Live Volume automatic failover occurs, vSphere HA can be configured to restart impacted virtual machines on the surviving array.

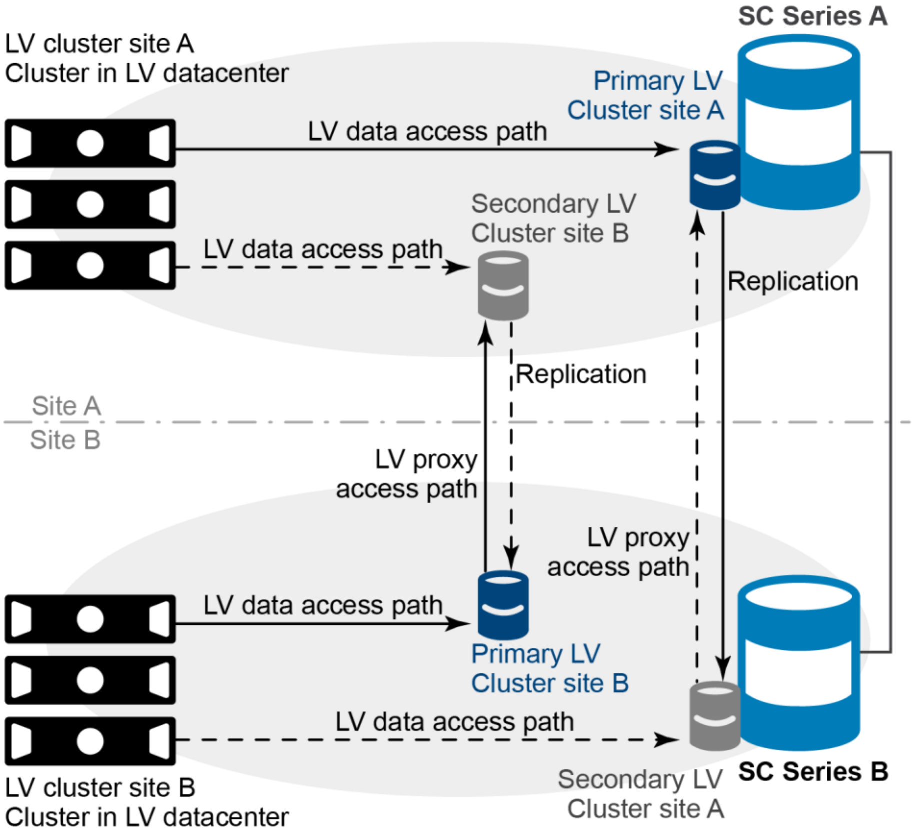


Figure 57 Live Volume data access in a non-uniform vSphere environment

The following vSphere advanced tuning should be configured for non-uniform stretched cluster configurations. This tuning allows HA to power off and migrate virtual machines during storage-related availability events after the primary Live Volume becomes available again using the Preserve Live Volume or Live Volume Failover Automatically feature.

Note: The Live Volume Failover Automatically feature is only supported with vSphere 5.5 and newer.

Set one of the following, depending on the vSphere version:

- vSphere 5.0u1+/5.1: Disk.terminateVMOnPDLDefault = True (/etc/vmware/settings file on each host) **or**
- vSphere 5.5+: VMkernel.Boot.terminateVMOnPDL = yes (advanced setting on each host, reboot required)

And set one of the following, depending on the vSphere version:

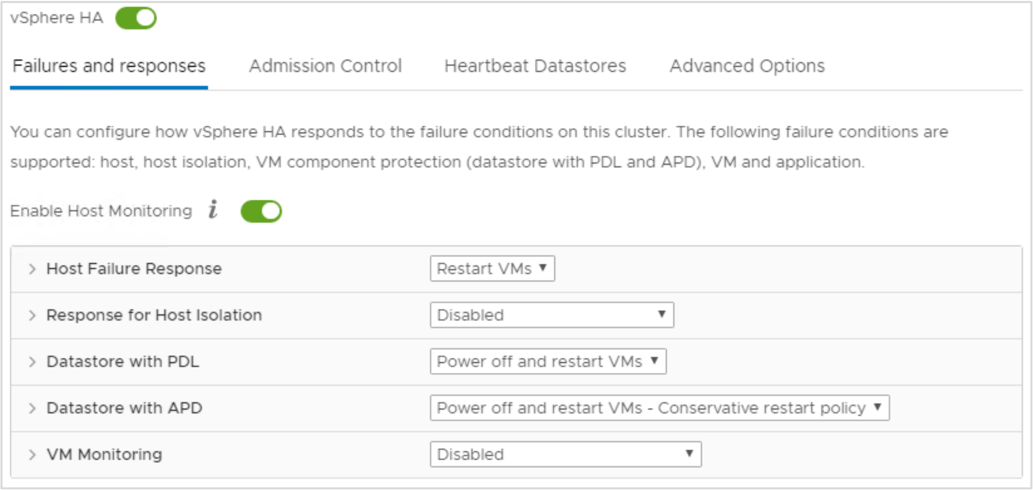
- vSphere 5.5: Disk.AutoremoveOnPDL = 0 (VMware-recommended non-default advanced setting on each host)
  or
- vSphere 6.0+: Disk.AutoremoveOnPDL = 1 (VMware-recommended default advanced setting on each host)

And set the following, regardless of the vSphere version:

- vSphere 5.0u1+: das.maskCleanShutdownEnabled = True (Cluster advanced options)

Configuring HA to restart VMs impacted by a non-uniform storage outage was improved in vSphere 6. In addition to supporting HA restart for Permanent Device Loss (PDL) events, HA restart can also react to All-Paths-Down (APD) events. The tuning becomes easier and more intuitive using the Web Client or HTML5 client in newer versions of vSphere.

1. It is recommended to configure VM Component Protection for PDL and APD events. For PDL events, select **Power off and restart VMs**. For APD events, VMware recommends selecting **Power off and restart VMs (conservative)**. For the advanced APD settings, refer to VMware documentation or the *VMware vSphere Metro Storage Cluster Recommended Practices* available on the VMware Documentation site.



You can configure how vSphere HA responds to the failure conditions on this cluster. The following failure conditions are supported: host, host isolation, VM component protection (datastore with PDL and APD), VM and application.

Enable Host Monitoring

Host Failure Response	Restart VMs
Response for Host Isolation	Disabled
Datastore with PDL	Power off and restart VMs
Datastore with APD	Power off and restart VMs - Conservative restart policy
VM Monitoring	Disabled

Figure 58 Configuring vSphere HA for PDL and APD conditions

The Disk.AutoremoveOnPDL advanced setting is not configurable in VMCP and should remain at its default value of 1 for each vSphere 6 host in the cluster. For more information on the Disk.AutoremoveOnPDL feature, refer to VMware KB article 2059622, PDL AutoRemove feature in vSphere 5.5 and vSphere 6.0.

In a non-uniform configuration, if an outage impacts primary Live Volume availability and Live Volume automatic failover cannot occur, vSphere HA will not be able to immediately restart impacted virtual machines.

If the VMware virtual infrastructure is version 4.0 or earlier, vSphere Metro Storage Cluster is not supported and other steps should be taken to prevent virtual machines from unexpectedly running from the secondary Live Volume. An individual VM or group of VMs may be associated with a DRS rule that keeps them together but this does not guarantee they will stay over a period of time on the same host or group of hosts where the primary Live Volume is located. As a last resort, DRS can be configured for manual mode or disabled when using Live Volume in a multi-site configuration that will prevent the automatic migration of VMs to Secondary Live Volume hosts in the same cluster.

VMware vSphere monitors SCSI sense codes sent by an array to determine if a device is in a PDL state. These SCSI sense codes are outlined in VMware KB article 2004684, Permanent Device Loss (PDL) and All-Paths-Down (APD) in vSphere 5.x and 6.x. SC Series storage supports two SCSI sense codes (see Table 1) which will be sent to vSphere hosts when a PDL condition is met.

Table 1 SCSI sense codes

SCSI sense code	Description
H:0x0 D:0x2 P:0x0 Valid sense data: 0x4 0x3e 0x1	LOGICAL UNIT FAILURE
H:0x0 D:0x2 P:0x0 Valid sense data: 0x5 0x25 0x0	LOGICAL UNIT NOT SUPPORTED

8.15 vSphere Metro Storage Cluster and Live Volume Requirements

A vSphere Metro Storage Cluster (vMSC) design with Live Volume requires the following:

- Dell SCOS 6.7 or newer with both SC Series arrays having the same firmware version
- Dell Storage Manager 2015 R2 or newer with tiebreaker service located at a site physically independent of SC Series arrays

- VMware vSphere 5.5 or newer
- SC Series best practices with VMware vSphere followed and configured
- Uniform or non-uniform storage presentation of volumes to vSphere hosts
- Fixed or Round Robin path selection policy (PSP)
- Live Volume with automatic failover with VMFS datastores or virtual mode raw device mappings (RDMs), with support for physical mode RDMs (added with SCOS 7.1)
- Live Volumes enabled to fail over automatically
- Fibre Channel or iSCSI synchronous high availability replication between SC Series arrays
- Maximum supported latency for synchronous high availability replication of 10 ms RTT
- Maximum supported latency of vSphere management network of 10 ms RTT
- Maximum supported latency from array to tiebreaker of 200 ms RTT
- Redundant vMotion network supporting a minimum throughput of 250 Mbps

8.16 VMware and Live Volume managed replication

Live Volume fulfills the needs of high availability use cases between two SC Series arrays in a local or stretched configuration. A third array can be added to the design to host a Live Volume managed replication. A managed replication is a replica of the primary Live Volume and may be either synchronous or asynchronous, depending on the type of replication used between the Live Volume pair. When Live Volume is configured to provide high availability intra site, the managed replication provides an additional level of data protection and recovery in the event of an unplanned outage impacting both Live Volume arrays. Live Volume managed replication and automatic failover are supported together. If an automatic failover occurs, the managed replication will follow the primary Live Volume which was automatically failed over.

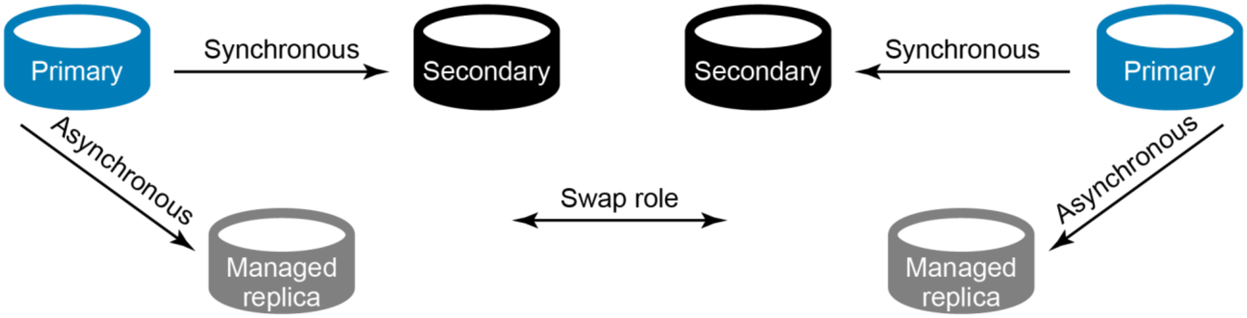


Figure 59 Synchronous Live Volume with asynchronous Live Volume managed replication

Although managed replications are controlled by Live Volume, they fundamentally work the same way as standard synchronous or asynchronous volume replication. This includes the recovery options available with view volumes and DR activation.

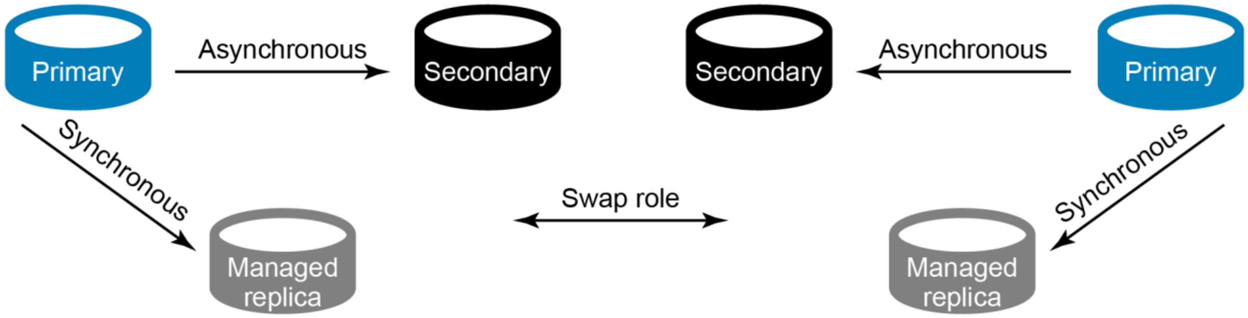


Figure 60 Asynchronous Live Volume with synchronous Live Volume managed replication

One differentiator between standard replication and Live Volume managed replication is that the source volume of a managed replication is dynamic and changes as Live Volume role swaps occur. The easiest way to think of this is to understand that the managed replication source is always the primary Live Volume. Because the primary Live Volume role can shift manually or automatically between arrays, the flow of replicated data will also seamlessly and automatically follow this pattern. The reason for this is that the primary Live Volume is the volume where write I/O is first committed. Therefore, and especially in an asynchronous Live Volume configuration, in the event of an unplanned outage or disaster that disables both Live Volumes, data should be recovered from the most transaction consistent volume to minimize loss of data. For synchronous Live Volumes, transaction inconsistency is less of an issue because both primary and secondary Live Volumes should have a sync status of current and not out of date unless the synchronous replication was paused or became out of date due to excess latency in high availability mode. Disaster recovery at a remote site is a good use case for the Live Volume managed replication feature. However, Live Volume managed replications are not explicitly supported with vSphere Site Recovery Manager. LUN presentation and data recovery on a managed replication can be handled automatically by DSM, but before virtual machines can be powered on, they must be registered into vSphere inventory, which may require a manual DR-documentation or scripted process.

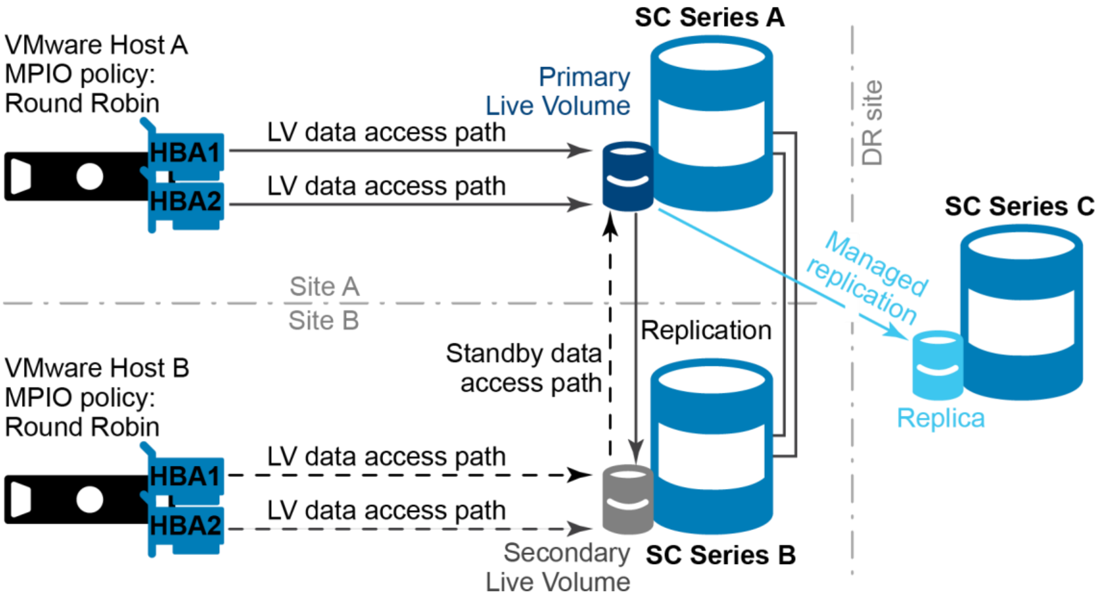


Figure 61 Non-uniform Live Volume pair with managed replication at a third site

9 Live Volume support for Microsoft Windows/Hyper-V

This section details aspects of the Live Volume feature set that are specific to Microsoft environments, such as best practices for MPIO settings and Live Volume automatic failover (LV-AFO), including ALUA support with SCOS 7.3. It is recommended to review the prior general sections of this document before proceeding in this section. In addition, review the VMware sections because Live Volume and MPIO behavior are very similar in both environments.

9.1 MPIO

Microsoft Windows or Hyper-V servers running 2008/R2 and newer versions on SC Series arrays can use the in-box Microsoft MPIO device specific module (DSM). The DSM comes with different MPIO policy options. The following policies are supported with Live Volume:

For SCOS 7.2 and prior:

- Round Robin (no ALUA support; all paths reported as optimized)
- Failover Only

For SCOS 7.3 and newer:

- Round Robin
- Failover Only
- Round Robin with Subset, Live Volume ALUA support (see limitations described in sections 9.3 and 9.4)

Note: For more information about Windows Server and MPIO policies, settings, and best practices, review the Dell EMC SC Series Storage and Microsoft Multipath I/O best practices guide.

9.2 Round Robin

The Round Robin policy spreads the read and write I/O evenly over all available data paths to a data volume without any consideration for latency or bandwidth for individual data paths. All available data paths are treated as optimal. Typically, this unintelligent yet simple approach is an ideal configuration in the following scenarios:

- If using non-uniform server mappings (where a host is presented with multiple data paths only to the SC Series array that is local to it)
- When the workload is local to the SC Series array that hosts the primary Live Volume(s)
- If bandwidth and latency performance are the same for all the available data paths

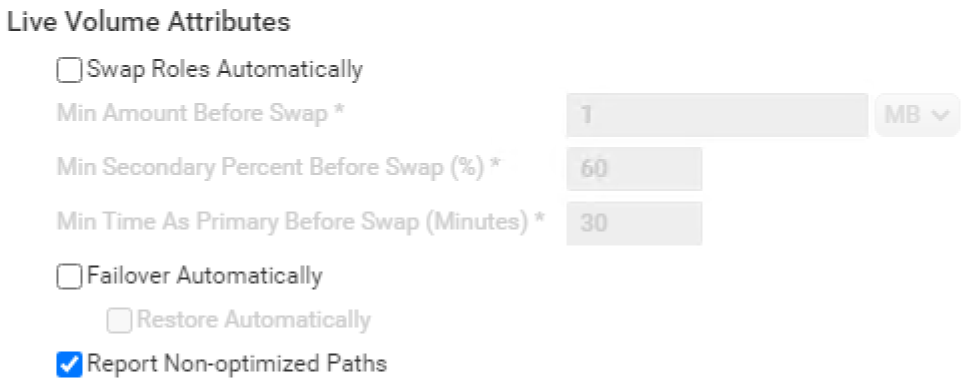
Round Robin also works well with uniform server mappings in the following cases:

- When both primary and secondary Live Volumes are accessible by high-bandwidth low-latency primary and secondary data paths.
- If the slight latency penalty caused by proxied data over secondary data paths does not negatively impact the workload.

In many cases, using non-uniform server mappings with Round Robin provides the best overall design while minimizing complexity, and it provides a good design baseline.

9.3 Round Robin with Subset (ALUA)

Round Robin with Subset (ALUA) is supported when a Live Volume is configured to report non-optimized paths to server hosts. This ability is available with SCOS 7.3 and newer, along with DSM 2018 R1 and newer. ALUA support is enabled by default when configuring a new Live Volume with SCOS 7.3.



Live Volume Attributes

□ Swap Roles Automatically

Min Amount Before Swap * 1 MB

Min Secondary Percent Before Swap (%) * 60

Min Time As Primary Before Swap (Minutes) * 30

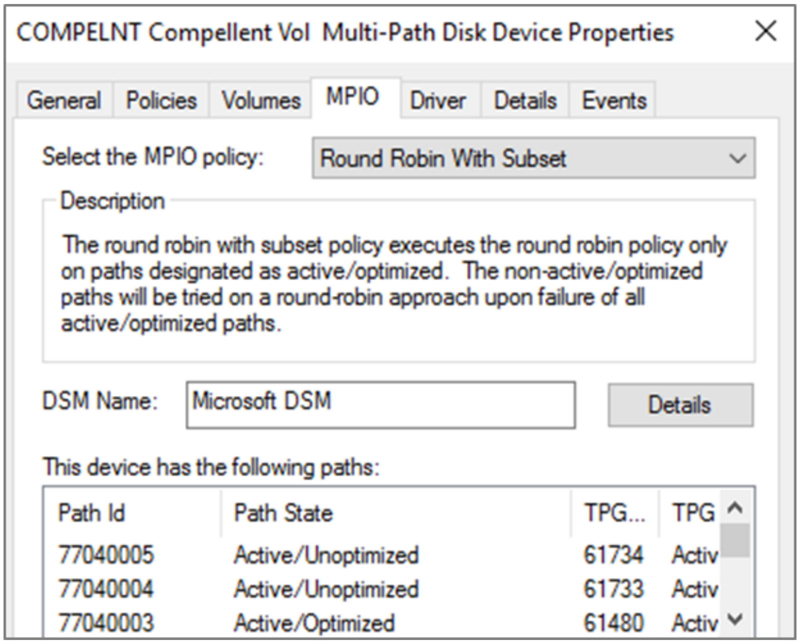
□ Failover Automatically

□ Restore Automatically

☑ Report Non-optimized Paths

Figure 62 Report Non-optimized Paths to a host server

A Windows server will detect the presence of non-optimal paths when this feature is enabled on a Live Volume. In the MPIO settings, the MPIO policy indicates Round Robin With Subset. In this example (with uniform server mappings), half of the paths are listed as Active/Optimized (paths to the primary Live Volume), and the other half are listed as Active/Unoptimized (paths to the secondary Live Volume). There are four of each kind of path, eight paths total. Figure 63 shows three paths; the other paths can be viewed by scrolling.



COMPELNT Compellent Vol Multi-Path Disk Device Properties

Select the MPIO policy: Round Robin With Subset

Description

The round robin with subset policy executes the round robin policy only on paths designated as active/optimized. The non-active/optimized paths will be tried on a round-robin approach upon failure of all active/optimized paths.

DSM Name: Microsoft DSM

This device has the following paths:

Path Id	Path State	TPG...	TPG
77040005	Active/Unoptimized	61734	Activ
77040004	Active/Unoptimized	61733	Activ
77040003	Active/Optimized	61480	Activ

Figure 63 Active Optimized and Unoptimized paths

9.4 Windows Server support limitations with Live Volume ALUA

Live Volume ALUA support with SCOS 7.3 and DSM 2018 R1 has use case limitations to be aware of.

In the process of developing this feature, it was found that the Microsoft implementation of MPIO incorrectly utilizes non-optimal paths when a stretch cluster node is configured to use non-uniform server mappings to a secondary Live Volume. In cases where no optimal paths are available, the Windows host will use a single available non-optimal path, instead of using Round Robin to spread the I/O over all available non-optimal paths. While a host configured to use only non-optimal paths to a secondary Live Volume (with non-uniform server mappings) is a legitimate use-case scenario by design with Live Volume ALUA, it is not a typical configuration encountered in the SAN industry, and this issue was not immediately apparent.

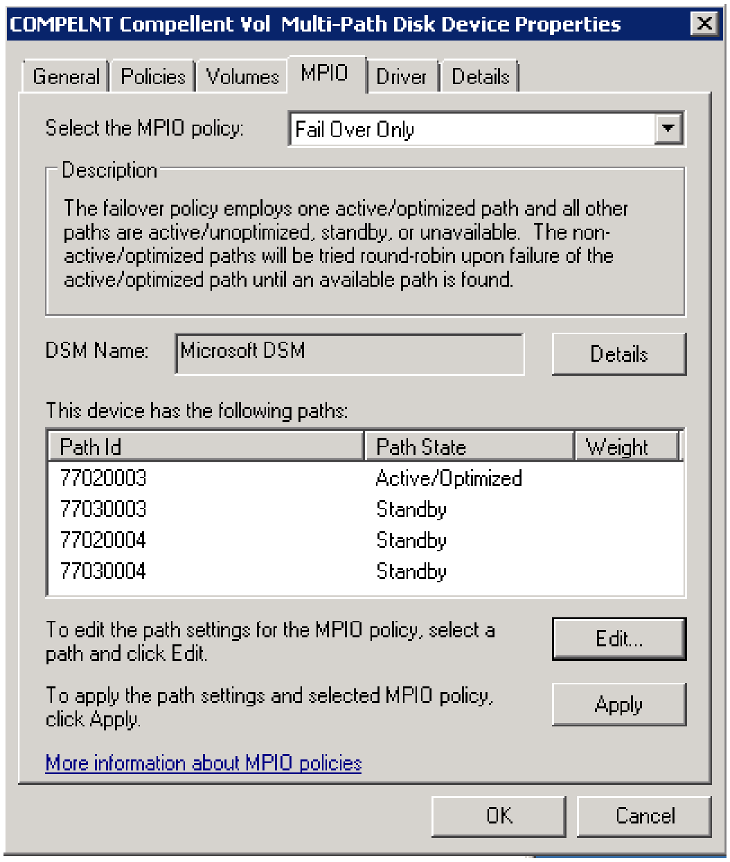
To address this limitation, install the March 2018 monthly cumulative update for Windows Server 2016. Microsoft does not plan to extend this fix to Windows Server operating systems prior to Windows Server 2016.

Customers should consider their design and decide whether to implement Live Volume ALUA support for their Windows Server hosts when using non-uniform server mappings with Live Volume. The following details the support for Windows Server:

- Windows Server 2016 with the March 2018 cumulative update and newer fully supports Live Volume ALUA.
- Windows Server 2012 R2 and prior: When using non-uniform server mappings for stretch cluster nodes, the recommendation is to uncheck the **Report Non-Optimal Paths** option, and the host server will detect and utilize all available paths as active-optimized.

9.5 Failover Only

With this MPIO policy, a primary data path is configured as active/optimized, and all other paths are set to standby. This policy is an option when using uniform server mappings and secondary data paths to the secondary Live Volume have limited bandwidth or higher latency that would negatively affect the workload, and the Windows Server operating system does not fully support Live Volume ALUA. Where supported, Round Robin with Subset typically is a better choice than Failover Only from a design and maintenance overhead standpoint.



COMPELNT Compellent Vol Multi-Path Disk Device Properties

Select the MPIO policy: Fail Over Only

Description

The failover policy employs one active/optimized path and all other paths are active/unoptimized, standby, or unavailable. The non-active/optimized paths will be tried round-robin upon failure of the active/optimized path until an available path is found.

DSM Name: Microsoft DSM

This device has the following paths:

Path Id	Path State	Weight
77020003	Active/Optimized	
77030003	Standby	
77020004	Standby	
77030004	Standby	

To edit the path settings for the MPIO policy, select a path and click Edit.

To apply the path settings and selected MPIO policy, click Apply.

Figure 64 Failover Only MPIO policy properties

9.6 Uniform server mappings with Live Volume and Round Robin

In Figure 65, a Round Robin Live Volume MPIO configuration is depicted. In this scenario, the server has two adapters and is mapped to both SC Series arrays that host the primary and secondary Live Volume pair. This configuration is referred to as uniform server mapping since the server is mapped to both SC Series arrays. Since all four paths are included in an MPIO Round Robin policy, about half of the storage traffic has to traverse the proxy link between the two SC Series arrays. In cases where the two SC Series arrays are well connected (for example, if they reside within the same data center), the slight latency penalty incurred for proxied data may be negligible for the workload, and this design would perform well. However, this configuration would be sub-optimal if there were significant latency or bandwidth limitations for the secondary paths, in which case, Round Robin with Subset or Failover Only would be a better choice.

Round Robin with uniform server mappings also prevents a Live Volume from automatically swapping roles (when the Swap Roles Automatically feature is enabled on a Live Volume) because about 50% of the traffic will always be going through each array and therefore the thresholds that trigger a role swap will not be exceeded.

The decision to use uniform or non-uniform server mappings in conjunction with MPIO Round Robin, Round Robin with Subset (with non-optimal paths reported to the host server), or Failover Only is a function of environmental variables that are unique to each customer. Because there are so many different configuration possibilities, administrators have great flexibility to tailor a solution that is best for their environment.

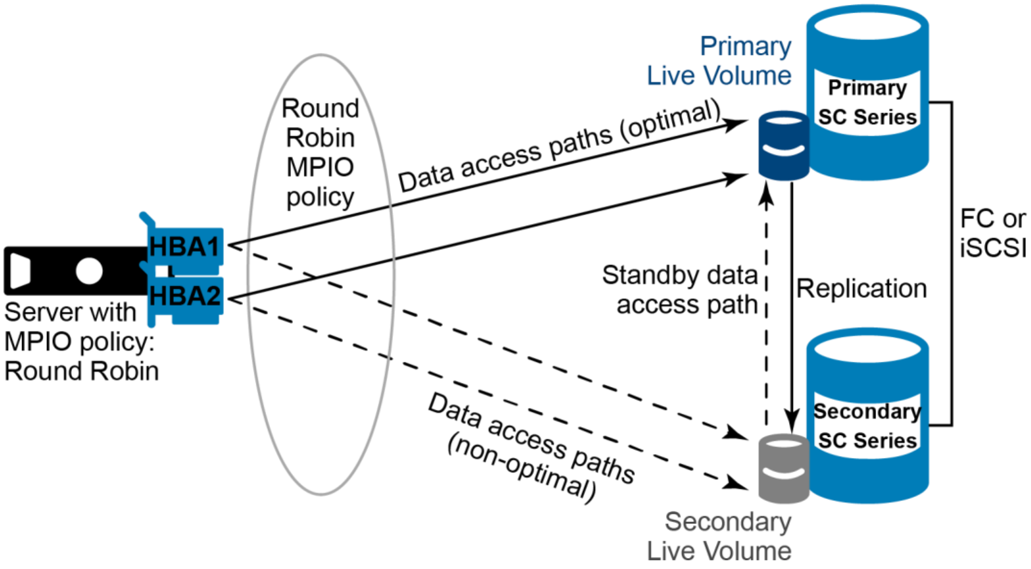


Figure 65 Uniform server mapping with MPIO

9.7 Hyper-V and Live Volume

The full Live Volume feature set works well with Microsoft Hyper-V in both clustered and non-clustered environments. These Live Volume features include support for synchronous and asynchronous replication, load balancing, disaster avoidance, managed replication, pre-defined DR plans, and other features covered in this document.

Note: Live Volume automatic failover (LV-AFO) supports host and guest clusters running Windows Server 2012 or newer, or Hyper-V 2012 or newer. More on LV-AFO is covered in section 9.9.

9.7.1 VM live migration and Live Volume automatic role swap

With clustered Hyper-V servers running Windows Server 2008 R2 and newer, live migration of virtual machines to another node can trigger a Live Volume automatic role swap. In order for automatic role swap to work (using a two-node Hyper-V cluster as an example), each node is mapped only to the SC Series array that is local to it. Therefore, when a VM workload is live migrated to the second node, the I/O will follow, and for a brief time, the I/O be proxied over secondary data paths until the auto role swap thresholds are exceeded. As noted previously, the Live Volume automatic role swap feature will not work when using MPIO Round Robin (all paths optimal) because the minimum I/O thresholds that trigger a role swap will not be exceeded.

9.7.2 Single-site configuration

In a single-site configuration, multiple Hyper-V servers can be mapped to both SC Series arrays for uniform server mappings. If latency and bandwidth are not a concern over secondary data paths, Round Robin is typically the best (and simplest) MPIO policy choice. If latency and bandwidth are a concern to non-optimal paths, configure the Live Volume to report non-optimized paths (SCOS 7.3 and newer) and leverage Live Volume ALUA if the OS fully supports Live Volume ALUA. This is the default setting for new Live Volumes configured with SCOS 7.3. Failover Only can also be used to limit I/O to a preferred optimized data path, but is typically more complicated to set up and maintain than Round Robin.

9.7.3 Multi-site configuration

In a multi-site stretch-cluster configuration, typically the individual Hyper-V hosts are mapped only to the SC Series array at that particular site, for a non-uniform mapping configuration. In this scenario, the best MPIO policy would typically be Round Robin for each Hyper-V host if the host does not fully support Live Volume ALUA (unpatched versions of Windows Server 2016 and prior). If the host OS fully supports Live Volume ALUA (Windows Server 2016 with the March 2018 cumulative update applied and newer), Round Robin with Subset is a better choice (with **Report Non-optimized paths** enabled for each Live Volume).

If Live Volume automatic role swap is enabled, the VM placement and workload determines which array will own the primary Live Volume, since the Live Volume will follow the workload, based on the auto-swap thresholds. The scenario in Figure 66 depicts a virtual machine that is live migrated from Host A to Host B. The secondary SC Series array will proxy I/O to the primary array for short time and then automatically swap the primary Live Volume role from the primary array to the secondary array.

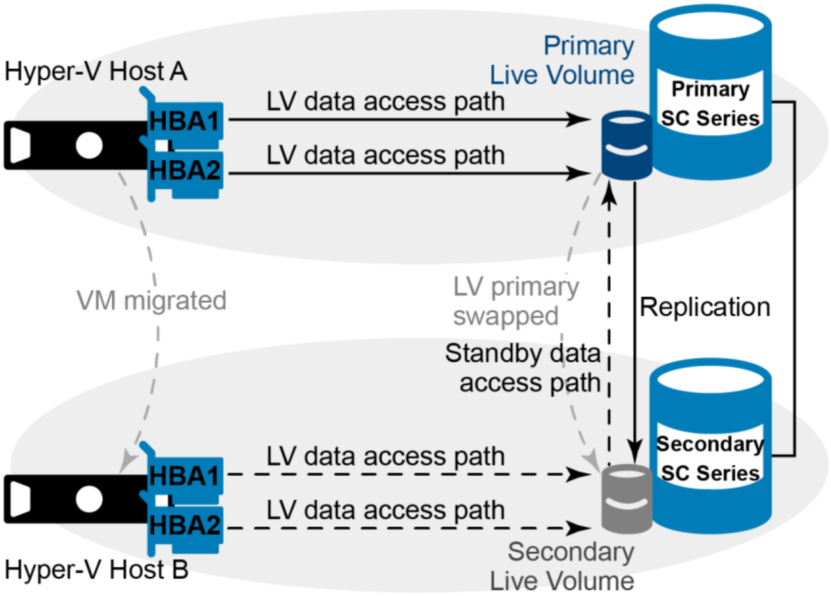


Figure 66 Non-uniform server access and Live Volume role swap

9.8 SCVMM/SCCM and Performance and Resource Optimization (PRO)

Microsoft System Center Virtual Machine Manager (SCVMM) with System Center Configuration Manager is capable of providing intelligent placement as well as automatic migrations of virtual machines from highly utilized nodes to lower utilized nodes, depending on the action setting of Automatic or Manual. If using Live Volume in a multi-site Hyper-V cluster with Performance and Resource Optimization (PRO) where there are latency and bandwidth limitations for secondary data paths, use the Manual action for virtual machine placement.

In a multi-site Live Volume Hyper-V cluster, the virtual machines will typically be kept running on nodes within the same site as their respective primary Live Volume(s). If PRO is activated on a Hyper-V cluster with nodes in each site, it could automatically migrate some of the virtual machines running on Cluster Shared Volumes (CSVs) that are also Live Volumes to a node that resides in the other data center, thereby splitting the I/O between data centers.

9.9 Live Volume and Cluster Shared Volumes

The Hyper-V Cluster Shared Volume (CSV) feature allows administrators to place multiple virtual machines on the volume in a way that VMs on different nodes can all have read and write access to the same volume concurrently. CSVs also have a resiliency feature called network redirection that by design makes Hyper-V cluster data access more fault tolerant. If the CSV is owned by a node in the cluster that has access to the volume, it can redirect data access to that volume through the network to another node that has lost access to that volume.

One of the best practices with CSVs is utilizing the ability to control which node is the CSV owner. Set the CSV to be owned by a cluster node that is in the primary site and mapped directly to the SC Series array. In this way, if the CSV goes into Network Redirected mode, the CSV owner is in the same site and downtime can be eliminated or reduced.

Figure 67 depicts a multi-site Hyper-V cluster with Live Volume. In this figure, the SC Series storage at Site B is offline. CSV network redirection can take over and proxy all the data traffic through the CSV owner on Host A.

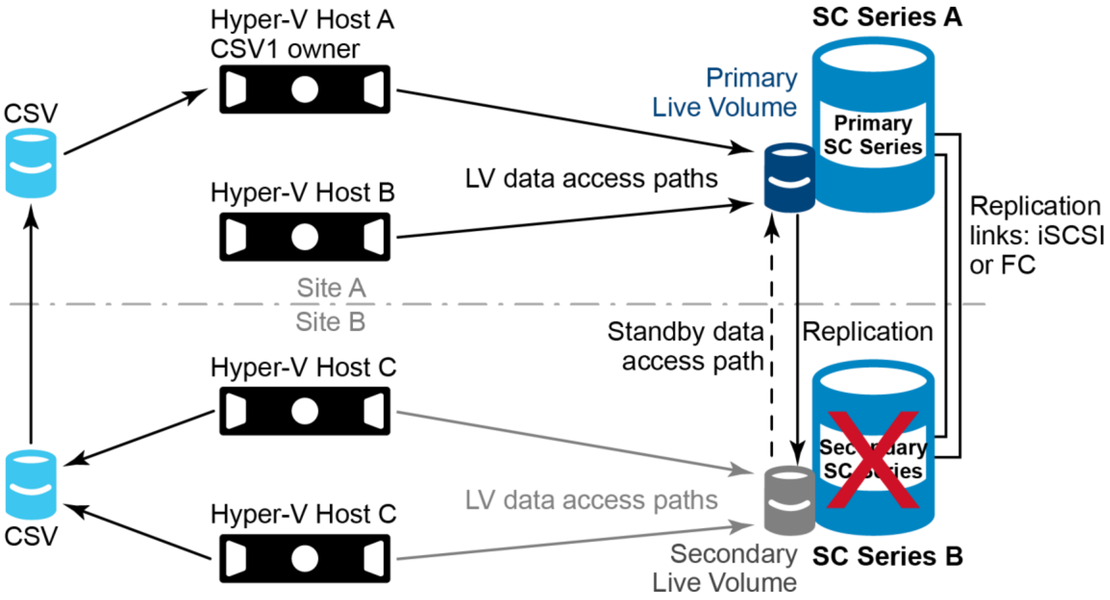


Figure 67 CSV resiliency with Live Volume and Network Redirection

If a failure happens that takes down SC Series B, Hyper-V can redirect access to the volume over the network using CSV Network Redirected access.

9.10 Live Volume automatic failover for Microsoft

Live Volume automatic failover (LV-AFO) is a feature enhancement that first became available with SCOS 6.7 and was supported initially in VMware environments only. See section 8 for more information on VMware support for LV-AFO.

With the release of SCOS 7.1 and Dell Storage Manager 2016 R2, support for LV-AFO was extended to Microsoft Window Server cluster and Hyper-V cluster environments in addition to VMware. LV-AFO functions essentially the same with Microsoft or VMware hosts, regarding triggers that cause a Live Volume to automatically fail over given a DR situation (see section 8.12). The main difference is that VMware offers some additional resiliencies with VM and workload recovery given a disaster.

To learn more about how LV-AFO works with Microsoft, including a deep dive into LV-AFO functionality and a lab demo, see the three-part video series, Live Volume with Auto Failover Support for Microsoft.

9.10.1 SC Series requirements for LV-AFO for Microsoft

The SC Series storage requirements to support LV-AFO for Microsoft are as follows:

- A pair of SC Series arrays that support Live Volume (SCv2000 Series is not supported)
  - Similarly configured SC Series arrays are recommended to ensure uniform performance
  - Dissimilar SC Series arrays are supported but performance will be no greater that the lower performing of the two SC Series arrays
- Replication and Live Volume feature licenses applied to both SC Series arrays
- SCOS 7.1 or newer on both SC Series arrays; both SC Series arrays should be running matching SCOS versions
- At least 1 Gbps of available bandwidth between the SC Series arrays for replication and proxied data (iSCSI or FC)
- No more than 5 to 10 ms of latency between the SC Series arrays and the host servers (higher latencies may be tolerable for some workloads but generally anything over 10 ms will start to be noticeable)
- An instance of the Dell Storage Manager at a third site to act as a tiebreaker/quorum witness for LV-AFO
  - DSM version 2016 R2 or newer is required to support LV-AFO for Microsoft; DSM 2018 or newer is required to support Live Volume ALUA.
  - DSM can be configured as a physical host or as a VM.
  - DSM supports running from a cloud-based service if the customer does not have third site.
  - This DSM instance should be dedicated to a tiebreaker/quorum witness role (run other DSM instances at the primary or secondary site for day-to-day management, monitoring, and reporting).
  - No more than 200 ms of round-trip latency is required between the DSM tiebreaker and each SC Series array.

9.10.2 Microsoft requirements for LV-AFO

Note: The LV-AFO feature requires Windows Server 2012 or newer.

The Microsoft requirements to support LV-AFO for Microsoft are as follows:

- Physical server clusters running Windows Server 2012 and newer
- Physical Hyper-V clusters running Windows Hyper-V 2012 or newer
  - Uniform or non-uniform host mappings to SC Series storage mappings are supported.
  - Fibre Channel or iSCSI transports are supported.
  - It is a best practice to avoid presenting Fibre Channel and iSCSI paths concurrently to the same volume (mixed transports) because it can result in unpredictable behavior with Microsoft clustering in some LV-AFO failure scenarios.
- Guest VM clusters running Windows Server 2012 and newer, that use the following methods for guest VM clustering:
  - Shared virtual hard disks with VHDX format (host servers require Hyper-V 2012 R2 in this case)
  - In-guest iSCSI (guest VMs running on either Hyper-V or VMware hosts are supported)
  - Physical raw device mappings (pRDMs) on VMware 5.5 or 6.0 hosts

Note: Each customer needs to make an informed choice about how they configure the quorum witness for a clustered environment that utilizes LV-AFO. The risk of an outage due to a temporary loss of quorum due to a less resilient design might be permissible in some cases, such as for test or development environments.

- Quorum witness: With Windows/Hyper-V clusters (physical or virtual), administrators can choose between a SAN-based quorum disk witness or a file share witness to serve as a tiebreaker. This is particularly important when there are equal numbers of nodes at each site, given a stretch cluster with LV-AFO. Configuring a quorum witness with Windows Server 2012 R2 Hyper-V and newer is recommended, regardless of the number of cluster nodes.
  - The optimal quorum configuration for LV-AFO is a file share witness that is located at a third site to ensure that the surviving node(s) at either site A or site B (given a complete site failure at either location) always have continuous, uninterrupted access to the quorum. This is true for both physical node clusters and guest VM clusters.
  - If a third site is not available for a file share witness, then the next best configuration is to use a SAN-based quorum disk that is also a Live Volume, configured for LV-AFO, so it can automatically fail over given a DR situation.

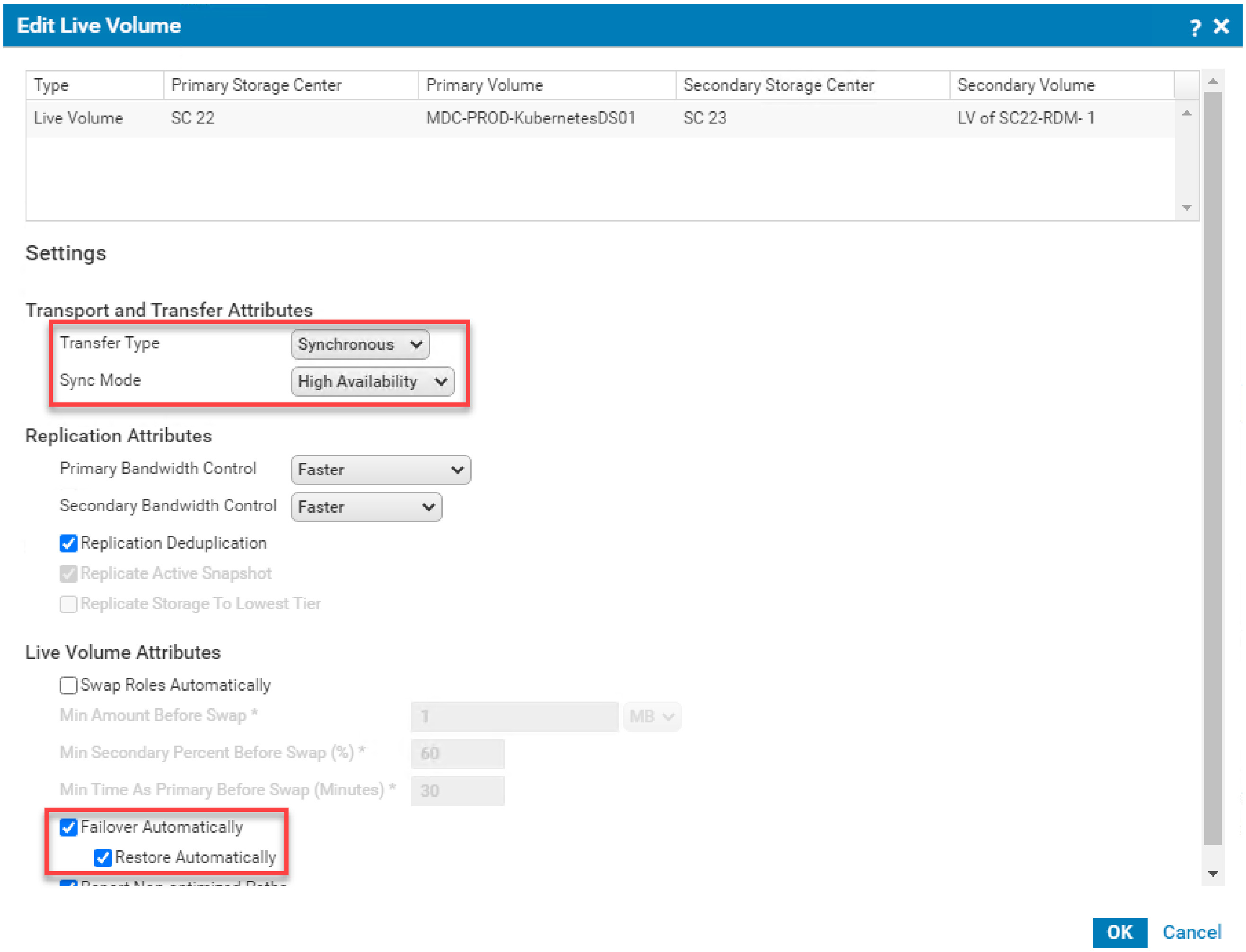
    However, this may not prevent loss of quorum given a complete site failure if the site that goes down hosts the quorum disk (as a primary LV), and it also hosts the node that owns the quorum disk. Given a complete site failure, if the quorum disk is configured for LV-AFO, it will fail over to the other site and become available as a primary LV to a surviving node. However, with a complete site failure, the combination of a surviving node needing to take ownership of the quorum disk, concurrent with the short pause in I/O to the quorum disk (20 to 30 seconds) while LV-AFO completes, may result in a failure of a surviving node to take ownership of the quorum disk. If this occurs, workloads dependent on cluster resources at the surviving site may go offline if the surviving nodes require a tiebreaker to achieve quorum, as would be the case if there are an equal number of cluster nodes at each site. To avoid this scenario, configure a file share witness at a third location.

  - Configuring a file share witness that is local to either site A or site B given a stretch cluster configuration with LV-AFO should be avoided. If the site that hosts the file share witness suffers a site outage, access to the file share witness by the surviving nodes at the surviving site will fail. If the file share witness is unavailable to the surviving nodes as a tiebreaker, and its vote is needed to maintain quorum, then cluster resources will go offline.

Note: There are two additional methods of guest VM clustering that have not been tested with LV-AFO: Windows Server guest VM clusters on Hyper-V that use pass-through disks, or virtual Fibre Channel disks as cluster disks. While they may work, they are not supported configurations with LV-AFO.

9.10.3 Enabling LV-AFO for a Live Volume

To enable LV-AFO, edit the settings for a Live Volume. Under **Replication Attributes**, make sure the **Type** is set to **Synchronous** and **Sync Mode** is set to **High Availability**. Once the correct sync mode is set, the Failover Automatically and Restore Automatically options become available at the bottom of the configuration screen. Check the box to enable **Failover Automatically**, and this will by default enable Restore Automatically as well. It is recommended to leave the **Restore Automatically** option enabled. This will minimize the amount of time a Live Volume is vulnerable to failure after an automatic failover occurs and the primary site comes back online. This will ensure that the Live Volume achieves a protected state as quickly as possible (fully synchronized) allowing automatic failback to occur, given another DR event that affects the secondary location.



Edit Live Volume

Type	Primary Storage Center	Primary Volume	Secondary Storage Center	Secondary Volume
Live Volume	SC 22	MDC-PROD-KubernetesDS01	SC 23	LV of SC22-RDM- 1

Settings

Transport and Transfer Attributes

Transfer Type: Synchronous

Sync Mode: High Availability

Replication Attributes

Primary Bandwidth Control: Faster

Secondary Bandwidth Control: Faster

☑ Replication Deduplication

☑ Replicate Active Snapshot

☐ Replicate Storage To Lowest Tier

Live Volume Attributes

☐ Swap Roles Automatically

Min Amount Before Swap *: 1 MB

Min Secondary Percent Before Swap (%) *: 60

Min Time As Primary Before Swap (Minutes) *: 30

☑ Failover Automatically

☑ Restore Automatically

☑ Report Non-optimized Paths

Figure 68 Enable Failover Automatically and Restore Automatically for a Live Volume

9.10.4 DR failure scenarios

Refer to section 8 for a list of DR events and how LV-AFO will function to protect the environment. The DR events that will cause a Live Volume to automatically fail over are platform agnostic; LV-AFO itself works the same given VMware or Windows Server/Hyper-V hosts or clusters. However, the steps necessary to recover VMs and workloads given a DR situation will be different based on the following:

- The nature, scope, and duration of the disaster
- The platform (VMware or Microsoft)
- The type of server mappings (uniform or non-uniform)
- Configuration of the workload.

In general, VMware (when configured) may offer more HA resiliency with its ability to automatically move and recover VMs and workloads at another location given a disaster.

9.10.5 Best practices for DSM tiebreaker placement with LV-AFO

One commonly asked question is about the placement of the Dell Storage Manager tiebreaker role, and if it needs to be installed at third site. The simple answer is, yes. From a best-practices standpoint, particularly for production workloads, it is critical to place the DSM tiebreaker at a third location to prevent site bias, which is explained in this section.

While nothing will prevent a customer from co-locating the DSM tiebreaker role at the same site as the primary or secondary Live Volume, cutting corners with this design puts the customer at an elevated risk of an unintended outage due to loss of LV-AFO quorum. To avoid confusion, the reference to LV-AFO quorum is separate, in addition to the Windows Server/Hyper-V quorum, as discussed in section 9.10.2.

For example, if the DSM tiebreaker is co-located at the same site as the secondary Live Volume, and this site suffers an outage so that the primary Live Volume loses connectivity to both the secondary Live Volume and DSM tiebreaker, the primary Live Volume will also go offline due to loss of quorum. The result is that there will be a complete outage for any workloads that use this Live Volume. This is by design. When the primary Live Volume loses connectivity to both the DSM tiebreaker and the secondary Live Volume concurrently (assuming the Live Volume pair is in sync at the time), the primary Live Volume has to assume that by becoming completely isolated (loss of quorum), that the DSM tiebreaker and secondary Live Volume are still online, and that the DSM tiebreaker is now promoting the secondary Live Volume to primary status.

Placing the DSM tiebreaker at the primary site with the primary Live Volume will help prevent an unintended loss of quorum, but only as long as the primary Live Volume stays at that site. If the primary Live Volume ever fails over (for any reason, manually or automatically) to the other site, then the customer is again vulnerable to an unintended loss of quorum and an outage due to site bias. To work around this, the customer could install another instance of DSM at the secondary site to manually seize the local tiebreaker role for that particular Live Volume if it ever fails over to that site, but this is not a very practical situation from an administration standpoint.

If the customer does not have a third site of their own for the DSM tiebreaker role, then a cloud service can be used. DSM can be installed on a physical host or a VM, as long as the OS is supported.

Each customer will need to make an informed choice about DSM tiebreaker placement. The risk of an outage due to unintended loss of quorum might be permissible in some cases, such as for test or development environments.

9.11 Live Volume with SQL Server

While SQL Server database files can be stored on Live Volumes, it is important to understand how a primary volume failure can impact database availability. If a database cannot be recovered after a primary volume failure, from either a frozen snapshot or the active snapshot on the secondary volume, a restore from backup will be required. Recovering from backup can greatly increase the time it takes to recover from a failure of the primary volume. If Live Volume is used across multiple sites, it is important to ensure that current database backups are always available at the secondary site.

Replay Manager cannot be used to protect SQL Server data stored on Live Volumes. Snapshots on a Live Volume will always be crash consistent. Unfortunately, database recovery from crash-consistent snapshots is not always successful, especially when database files are spread across multiple volumes. While generally not a best practice, placing all files for a given database on the same volume will increase the odds of a successful recovery from crash-consistent snapshots.

As long as the primary and secondary volumes are synchronized, database recovery should be reliable from the active snapshot on the secondary volume, if the primary volume fails. Since asynchronous Live Volume does not keep the primary and secondary volumes synchronized, synchronous Live Volume should be used for SQL Server database files. If synchronous Live Volume is used in high availability mode, the secondary volume may not always be in sync with the primary. A successful recovery from the active snapshot on the secondary volume may not be possible if it is out of sync. Synchronous Live Volume in high consistency mode provides the best protection.

Live Volume with automatic failover can be used to create a multi-site failover cluster instance of SQL Server. As long as the sites are synchronized, SQL Server will automatically bring the instance online at the secondary site if the primary site were to fail. If Live Volume is set up in a uniform configuration, it is possible for SQL Server to be running in one site and the primary volume in another. Using Live Volume in a non-uniform configuration, where each node of the cluster only has volume mappings to the local array and with automatic role swap enabled, will help ensure that SQL Server and the primary volume are running at the same site. Since Live Volume with automatic failover uses synchronous replication in high availability mode, the secondary volume is not guaranteed to always be in sync with the primary. If a failure occurs while the secondary is out of sync, manual intervention will be required to recover the SQL Server instance.

If automatic failover is not needed, regular replication may be a better choice to protect SQL Server data. Replication alone offers recovery times comparable to Live Volume without losing the protection benefits of application-consistent snapshots provided by Replay Manager, reducing the risk of having to recover from backup in the event of a failure. The entire recovery can be scripted using Microsoft PowerShell®, reducing recovery time and minimizing mistakes.

10 Live Volume with Linux/UNIX

Synchronous replication is a feature of SC Series that allows two copies of data to be maintained on separate SC Series arrays using one or multiple replication relationships. These two arrays can be in the same location, or can be geographically dispersed and connected by a WAN. Synchronous replication functionality is subdivided into two user-configurable operating modes, high consistency and high availability; these two modes are discussed in further detail in section 3.1. Additionally, the synchronous replication mode can be changed "on demand" depending on the needs of the customer.

Note: The serial number of the replicated volume on the destination SC Series array is unique, and different from that of the source volume.

When Live Volume is coupled with synchronous replication, it allows customers to deploy and manage identical data integrity guaranteed copies of data to a secondary SC Series array at an alternate location. The use of Live Volume creates value in this scenario, by masking the serial number of the replicated volume on the destination SC Series array and making the serial number appear identical to that of the source volume. The ability to maintain an identical serial number volume (or volumes) on the destination SC Series array simplifies and expedites the ability to recover from this volume (or volumes) into the destination application stack.

10.1 Live Volume and Synchronous Replication

The use of Live Volume in conjunction with synchronous replication in Red Hat® Enterprise Linux® deployments offers customers the ability to safely and resiliently manage, back up, and recover their business-critical data across both single- and multi-site deployments.

The remainder of this section discusses some of these use cases along with certain technical considerations in these scenarios, respectively.

10.2 Live Volume managed replication

Live Volume managed replication (LVMR) is the ability of SC Series arrays to replicate and manage a third copy of data. It is always attached to the primary SC Series array in a Live Volume scenario. If the SC Series roles are swapped, the LVMR volume will always follow the array that assumes the primary role. The mode of replication used for the LVMR volume is described in Table 2, which shows there is a maximum of one synchronous replication pair in any scenario.

Table 2 Live Volume replication modes

Live Volume at Site A	Replication mode of Live Volume to site B	Replication mode of LVMR to site C
Live Volume	Synchronous	Asynchronous
	Asynchronous	Synchronous
	Asynchronous	Asynchronous

An LVMR volume (in asynchronous mode with active snapshot/Replay enabled, or in synchronous mode) can be used to manage and provide an offsite copy of business-critical data for disaster recovery or data distribution use cases (where locating data closer to the audience could significantly reduce data access latency). Figure 69 depicts this scenario.

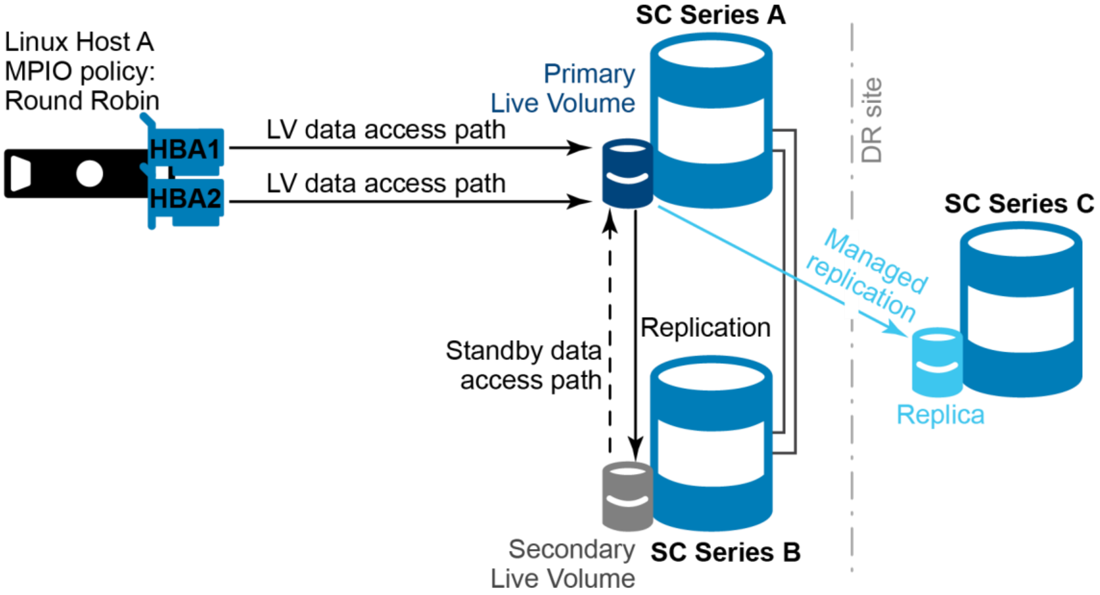


Figure 69 Live Volume with managed replication

10.3 Live Volume automatic failover

Live Volume is supported on any Linux platform that is supported by SCOS. For the list of Linux platforms supported by SCOS, refer to the Dell EMC Storage Compatibility Matrix.

As of SCOS 7.3, the Live Volume automatic failover feature has not been fully tested on the Linux platform and therefore it is not a supported configuration.

10.4 Live Volume and Linux MPIO

As discussed in previous sections, Live Volumes can be configured in uniform or non-uniform configurations. In a uniform configuration, Live Volumes are mapped on the Linux host from both primary and secondary SC Series arrays. An MPIO solution is required on the Linux host to manage these paths and direct I/O to the paths in a way defined by the software load-balancing and failover directives. Currently on the Linux platform, Device Mapper Multipath (DM-Multipath) is the only supported MPIO solution for Live Volumes. In a non-uniform configuration, Live Volumes are mapped on the Linux host from either the primary or secondary SC Series array. If there are multiple storage paths to the same array for storage controller redundancy and high availability, DM-Multipath is needed to provide load-balancing and failover capabilities between these storage paths.

10.4.1 DM-Multipath configuration

DM-Multipath comes with built-in default settings for SC Series arrays. These default settings are not reflected in the /etc/multipath.conf file. To display these settings, execute **multipathd -k"show config"** and look for the device section for **"COMPELNT".**

It is recommended to examine the settings closely especially when Live Volumes are involved because the built-in default settings might not be appropriate. The following sample configuration demonstrates a version of the multipath configuration:

```
defaults {
         find_multipaths yes
         user_friendly_names yes
         polling_interval 5
}
devices {
        device {
                vendor "COMPELNT"
                product "Compellent Vol"
                path_grouping_policy "multibus"
                path_checker "tur"
                features "0"
                hardware_handler "0"
                prio "const"
                failback immediate
                rr_weight "uniform"
                no_path_retry "24"
                fast_io_fail_tmo 5
                dev_loss_tmo infinity
                path_selector "round-robin 0"
        }
}
```

This configuration is designed with the following assumptions:

- The storage arrays are fully redundant and are protected for complete outage.
- Storage paths are expected to be highly available within an SC Series array and across remote arrays.
- In the event of path failovers, I/O is queued and retried for up to 24 times. Each retry interval is 5 seconds. Therefore, it tolerates a maximum of 2 minutes (24 x 5 seconds) of path unavailability before it stops retrying. This timeout needs to be long enough to cover the controller failover within an SC Series array and the Live Volume swap role between the primary and secondary array. Adjust this value if necessary to adapt to your environment.
- It is recommended to explicitly include the **COMPELNT** device settings in **/etc/multipath.conf** file even though the built-in defaults might cover it. Several reasons for this recommendation are:
  - It prevents an unexpected change of behavior due to unannounced changes on these default settings in future releases of DM-Multipath.
  - It overrides the defaults and allows finer control on COMPELNT-specific settings, such as no_path_retry, path_grouping_policy and prio.

- While device **path_selector** policies **service-time** and **round-robin** are supported by DM-Multipath, Dell Technologies has performed extensive testing with **round-robin** policy only. See Figure 65.
- In a uniform configuration where primary and secondary paths are mapped to the Linux host, these paths are grouped into a single group and the **round-robin** policy spreads I/O to these paths with equal weight even though the secondary paths might have higher latency. This is because I/O issued to the secondary paths is proxied through the replication link to the primary SC Series array as described in section 5.2. Hence, the overall application performance would be limited by the slowest paths.

10.5 Live Volume with ALUA

SCOS 7.3 enhances Live Volume with the introduction of the ALUA capability. ALUA-optimized Live Volumes report the preferred storage access paths to the host by indicating which paths are optimized and non-optimized. In a uniform configuration, paths from the primary Live Volume are seen as **optimized,** while paths from the secondary Live Volume are seen as **non-optimized**. With proper configuration in the host's MPIO software, the host can direct I/O only to the **optimized** storage paths, improving the overall I/O latency and performance by avoiding sending I/O through the slower paths.

Note: As of SCOS 7.3, the ALUA optimization feature has not been fully tested on the Linux platform. Therefore, it is not recommended to enable the feature.

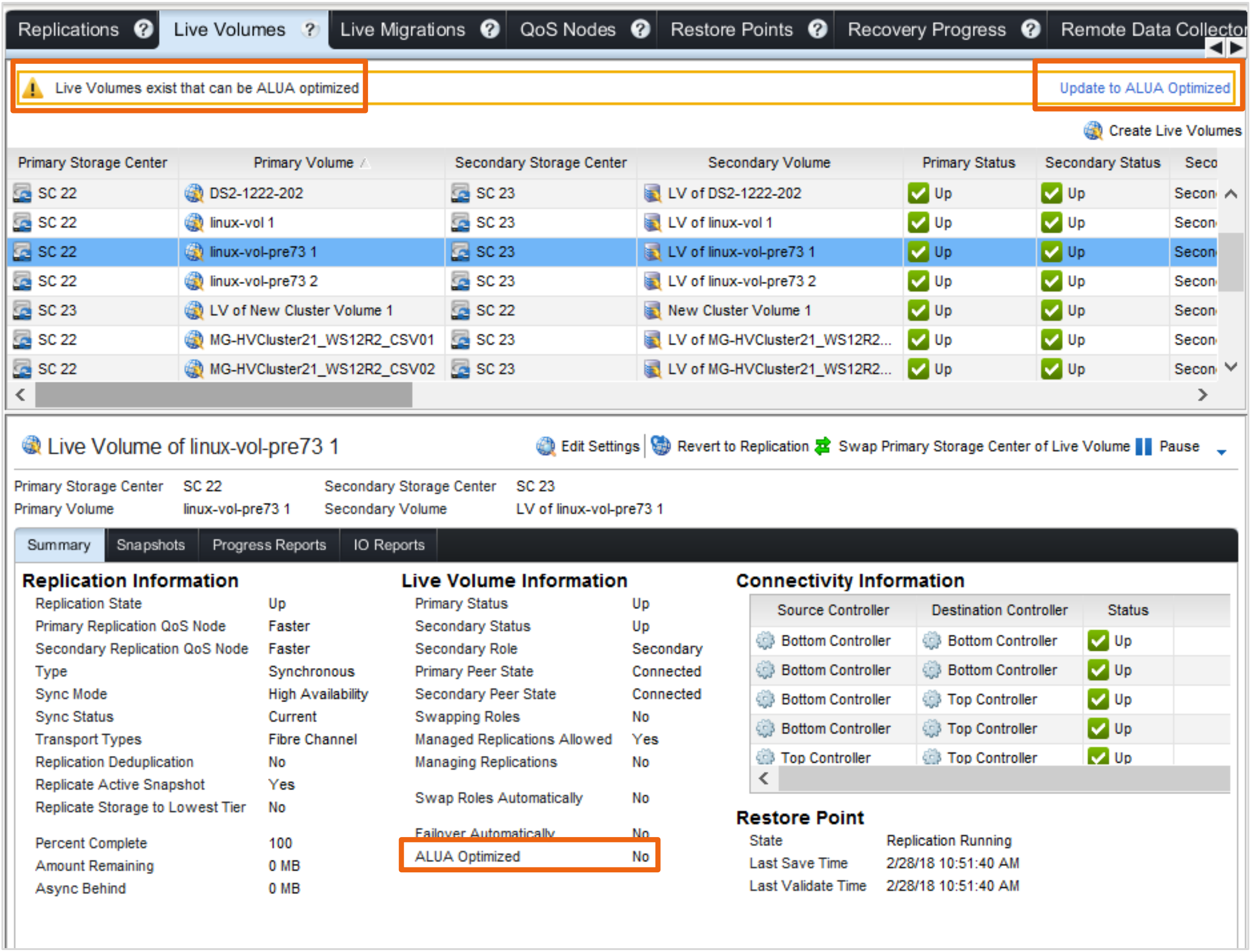
10.5.1 Disable ALUA prioritization in DM-Multipath configuration

For reasons mentioned in the previous section, DM-Multipath ALUA settings should be avoided as of SCOS 7.3. Therefore, do not set **prio alua** for **COMPELNT** devices in the **/etc/multipath.conf** file. Rather, use **prio const** in the COMPELNT device stanza as shown in 10.4.1.

10.5.2 Existing Live Volumes created before SCOS 7.3

For existing Live Volumes created before SCOS 7.3, ensure that these volumes have an **ALUA Optimized** status of **No** in DSM and are excluded from being upgraded to ALUA-optimized.

After SCOS is upgraded to 7.3, DSM displays a banner in the Live Volume tab indicating that there are existing Live Volumes that can be optimized for ALUA. Select any Live Volume on the list to see the existing **ALUA Optimized** status. See Figure 70.



⚠ Live Volumes exist that can be ALUA optimized

Update to ALUA Optimized

Primary Storage Center	Primary Volume	Secondary Storage Center	Secondary Volume	Primary Status	Secondary Status	Seco
SC 22	DS2-1222-202	SC 23	LV of DS2-1222-202	✓ Up	✓ Up	Secon
SC 22	linux-vol 1	SC 23	LV of linux-vol 1	✓ Up	✓ Up	Secon
SC 22	linux-vol-pre73 1	SC 23	LV of linux-vol-pre73 1	✓ Up	✓ Up	Secon
SC 22	linux-vol-pre73 2	SC 23	LV of linux-vol-pre73 2	✓ Up	✓ Up	Secon
SC 23	LV of New Cluster Volume 1	SC 22	New Cluster Volume 1	✓ Up	✓ Up	Secon
SC 22	MG-HVCluster21_WS12R2_CSV01	SC 23	LV of MG-HVCluster21_WS12R2...	✓ Up	✓ Up	Secon
SC 22	MG-HVCluster21_WS12R2_CSV02	SC 23	LV of MG-HVCluster21_WS12R2...	✓ Up	✓ Up	Secon

Live Volume of linux-vol-pre73 1

Primary Storage Center	SC 22	Secondary Storage Center	SC 23
Primary Volume	linux-vol-pre73 1	Secondary Volume	LV of linux-vol-pre73 1

Replication Information

Replication State	Up
Primary Replication QoS Node	Faster
Secondary Replication QoS Node	Faster
Type	Synchronous
Sync Mode	High Availability
Sync Status	Current
Transport Types	Fibre Channel
Replication Deduplication	No
Replicate Active Snapshot	Yes
Replicate Storage to Lowest Tier	No
Percent Complete	100
Amount Remaining	0 MB
Async Behind	0 MB

Live Volume Information

Primary Status	Up
Secondary Status	Up
Secondary Role	Secondary
Primary Peer State	Connected
Secondary Peer State	Connected
Swapping Roles	No
Managed Replications Allowed	Yes
Managing Replications	No
Swap Roles Automatically	No
Failover Automatically	No
ALUA Optimized	No

Connectivity Information

Source Controller	Destination Controller	Status
Bottom Controller	Bottom Controller	✓ Up
Bottom Controller	Bottom Controller	✓ Up
Bottom Controller	Top Controller	✓ Up
Bottom Controller	Top Controller	✓ Up
Top Controller	Top Controller	✓ Up

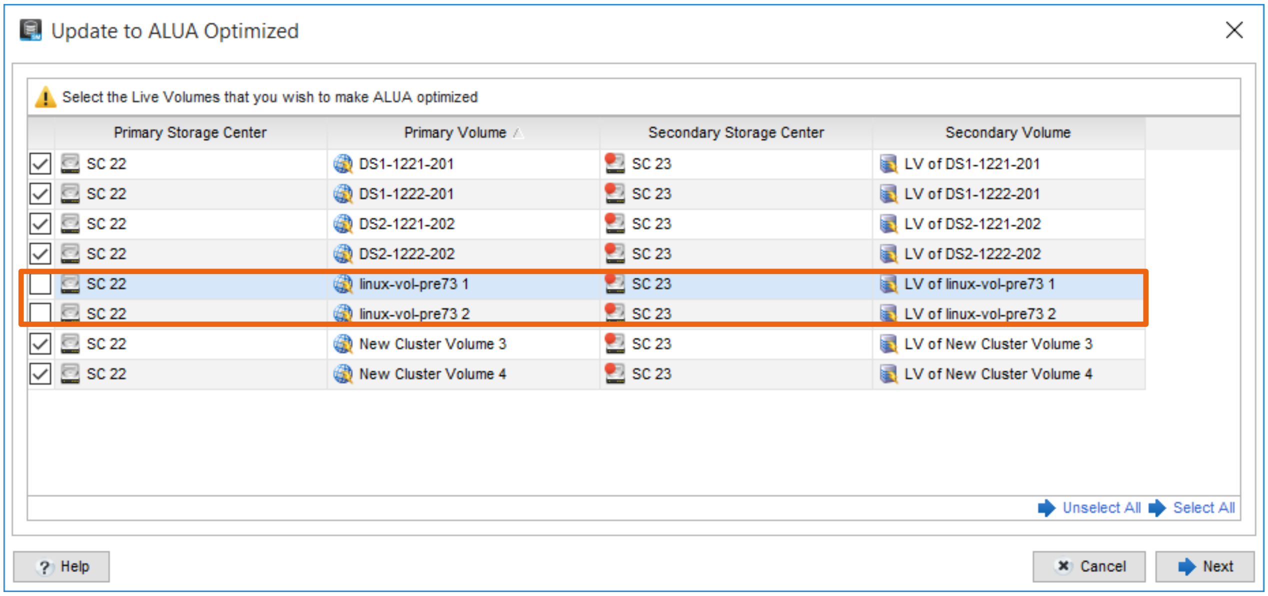
Restore Point

State	Replication Running
Last Save Time	2/28/18 10:51:40 AM
Last Validate Time	2/28/18 10:51:40 AM

Figure 70 Live Volume ALUA optimization banner and ALUA optimization status

Live Volumes created before SCOS 7.3 do not automatically become ALUA optimized. The storage administrator must click the **Update to ALUA Optimized** link to initiate the optimization process. The link opens a pop-up window that shows all Live Volumes that are eligible for optimization. See Figure 71. To ensure Linux Live Volumes do not get ALUA optimized, unselect them from the list.

Note: By default, all eligible Live Volumes are selected. It is important to make sure the Linux Live Volumes are unselected from the list. These Live Volumes will remain on the list and need to be unselected the next time the storage administrator optimizes other Live Volumes.



Update to ALUA Optimized

Select the Live Volumes that you wish to make ALUA optimized

	Primary Storage Center	Primary Volume	Secondary Storage Center	Secondary Volume
☑	SC 22	DS1-1221-201	SC 23	LV of DS1-1221-201
☑	SC 22	DS1-1222-201	SC 23	LV of DS1-1222-201
☑	SC 22	DS2-1221-202	SC 23	LV of DS2-1221-202
☑	SC 22	DS2-1222-202	SC 23	LV of DS2-1222-202
□	SC 22	linux-vol-pre73 1	SC 23	LV of linux-vol-pre73 1
□	SC 22	linux-vol-pre73 2	SC 23	LV of linux-vol-pre73 2
☑	SC 22	New Cluster Volume 3	SC 23	LV of New Cluster Volume 3
☑	SC 22	New Cluster Volume 4	SC 23	LV of New Cluster Volume 4

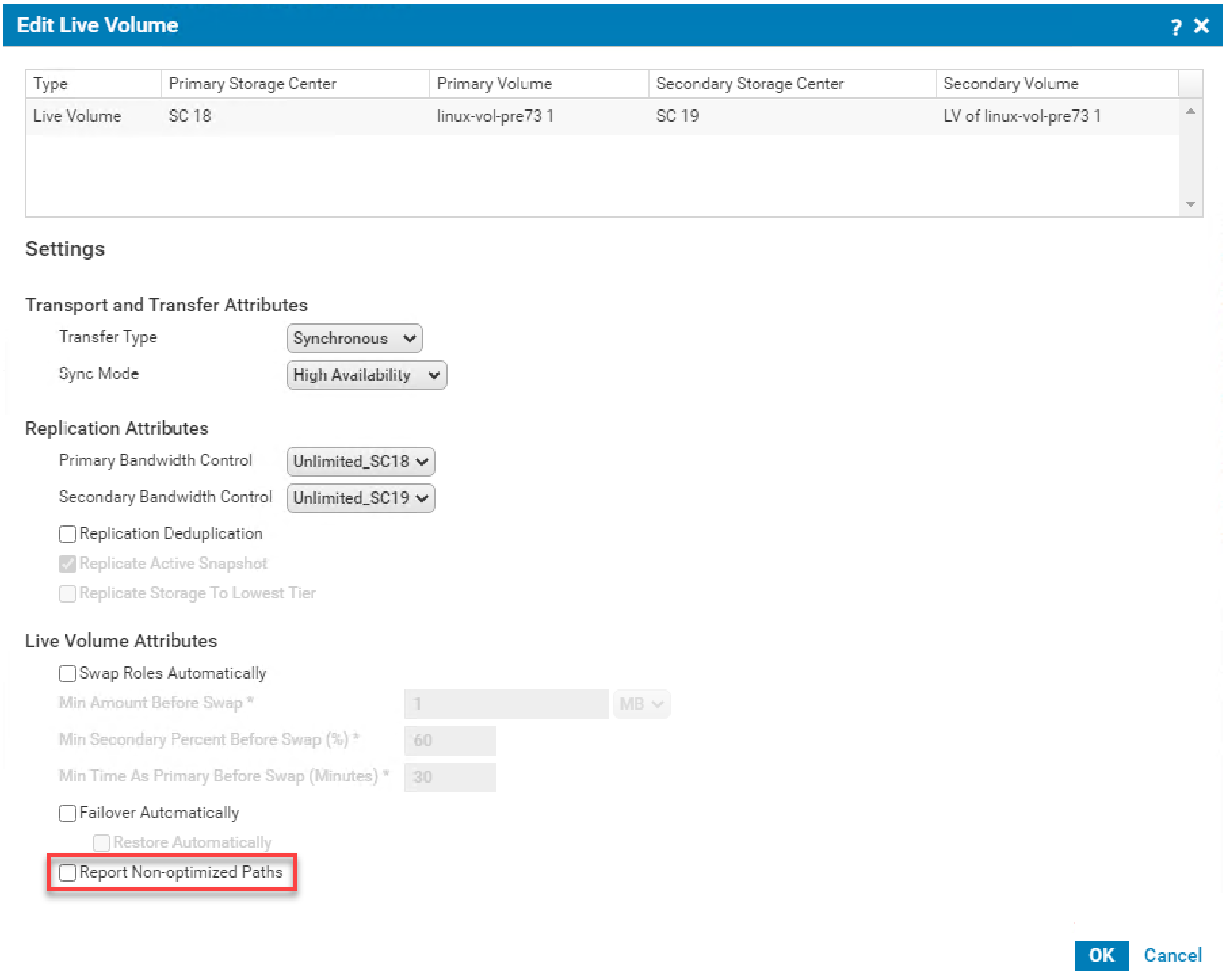
Figure 71 Unselect Linux Live Volumes from the update list

In the event that Linux Live Volumes created before SCOS 7.3 are optimized, the Linux hosts might experience temporary I/O interruption during the optimization process. The length of the interruption varies depending on the host's DM-Multipath configuration. Internal testing showed this can range from a few seconds to a couple minutes.

10.5.3 Disable reporting ALUA optimization

As discussed in section 10.5, it is not recommended to optimize Live Volumes for ALUA on the Linux platform. Once a Live Volume is optimized for ALUA, it cannot be undone. However, the ALUA-optimized Live Volume can be set to behave like a non-optimized Live Volume.

The **Report Non-optimized Paths** setting can be found under the **Edit Live Volume Settings** screen (Figure 72). By unchecking this option, SCOS stops reporting the non-optimized ALUA status of the storage path to the Linux host. As a result, all paths on the Linux host appear as active and optimized, regardless of the primary and secondary SC Series arrays. This is the same behavior on a system with SCOS prior to 7.3. Disabling the **Report Non-optimized Paths** option does not interrupt host I/O, and therefore it is safe to execute at any time.



Edit Live Volume

Type	Primary Storage Center	Primary Volume	Secondary Storage Center	Secondary Volume
Live Volume	SC 18	linux-vol-pre73 1	SC 19	LV of linux-vol-pre73 1

Settings

Transport and Transfer Attributes

Transfer Type: Synchronous

Sync Mode: High Availability

Replication Attributes

Primary Bandwidth Control: Unlimited_SC18

Secondary Bandwidth Control: Unlimited_SC19

☐ Replication Deduplication

☑ Replicate Active Snapshot

☐ Replicate Storage To Lowest Tier

Live Volume Attributes

☐ Swap Roles Automatically

Min Amount Before Swap *: 1 MB

Min Secondary Percent Before Swap (%) *: 60

Min Time As Primary Before Swap (Minutes) *: 30

☐ Failover Automatically

☐ Restore Automatically

☐ Report Non-optimized Paths

Figure 72 Disable ALUA status reporting

10.5.4 Creating new Live Volumes on SCOS 7.3

All new Live Volumes created on SCOS 7.3 are ALUA-optimized. If the Live Volumes are intended for the Linux platform, ensure the **Report Non-optimized Paths** setting is unchecked during the creation of the Live Volume, or follow section 10.5.3 to update the setting after the Live Volume is created.

Because the Live Volumes are created as already ALUA-optimized on the SC Series array, even though it is not reporting the non-optimized status, these Live Volumes would not show up in the **Update to ALUA optimized** list (Figure 71).

10.6 Identify parent SC Series arrays for Linux storage paths

This section provides information on how to correlate the Linux device paths to the SC Series arrays. The following exercise demonstrates the process to show the Fibre Channel ports on the SC Series arrays associated with each Linux device paths. The same process also applies to iSCSI transport. The information might be helpful for troubleshooting path failures or performance related issues.

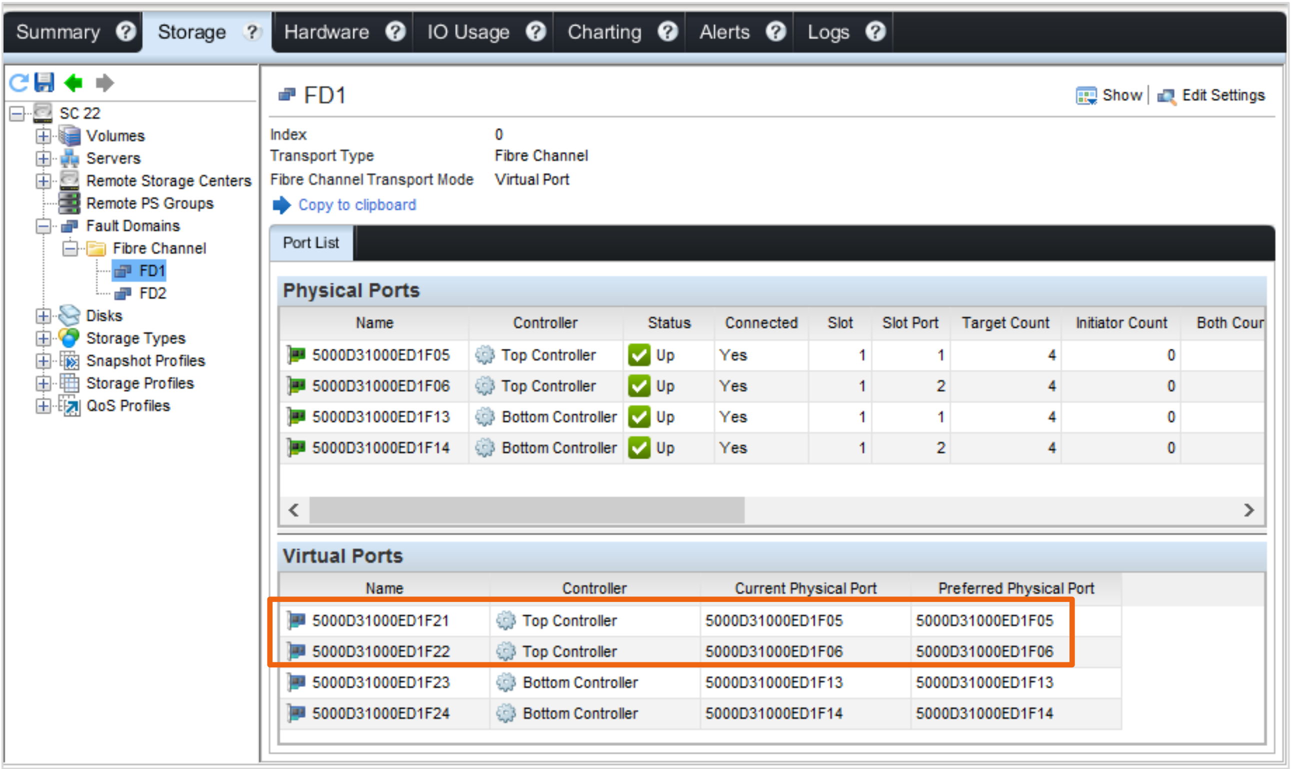
a) Show the paths information with multipath command. Note the H:C:T (Host adapter, Controller, Target) and the sd devices information. In this example, a Live Volume has eight storage paths.

```
# multipath -ll mpatha
mpatha (36000d31000ed1f0000000000000000b6) dm-2 COMPELNT,Compellent Vol
size=100G features='1 queue_if_no_path' hwhandler='0' wp=rw
`-+- policy='round-robin 0' prio=1 status=enabled
  |- 0:0:0:1  sdb 8:16  active ready running
  |- 7:0:0:1  sde 8:64  active ready running
  |- 0:0:15:1 sdh 8:112 active ready running
  |- 7:0:15:1 sdi 8:128 active ready running
  |- 0:0:3:1  sdc 8:32  active ready running
  |- 7:0:3:1  sdf 8:80  active ready running
  |- 0:0:4:1  sdd 8:48  active ready running
  `- 7:0:4:1  sdg 8:96  active ready running
```

b) Execute the **lsscsi** command to show the transport information. Note the transport column (third field) contains the SC Series target port number.

```
# lsscsi --transport
[0:0:0:1]    disk    fc:0x5000d31000ed1f220x1b0b02   /dev/sdb
[0:0:3:1]    disk    fc:0x5000d31000ed21210x1b1201   /dev/sdc
[0:0:4:1]    disk    fc:0x5000d31000ed21220x1b1301   /dev/sdd
[0:0:15:1]   disk    fc:0x5000d31000ed1f210x1b0a02   /dev/sdh
[1:0:0:0]    disk    sata:                           /dev/sda
[5:0:0:0]    cd/dvd  sata:                           /dev/sr0
[7:0:0:1]    disk    fc:0x5000d31000ed1f260x1c0b02   /dev/sde
[7:0:3:1]    disk    fc:0x5000d31000ed21250x1c1201   /dev/sdf
[7:0:4:1]    disk    fc:0x5000d31000ed21260x1c1301   /dev/sdg
[7:0:15:1]   disk    fc:0x5000d31000ed1f250x1c0a02   /dev/sdi
```

c) In DSM, navigate to the Fibre Channel fault domain tabs. If the array is configured in Virtual Port mode, go to the Virtual Ports screen. In this example, the Virtual Ports information for both primary and secondary SC Series arrays are examined.



FD1

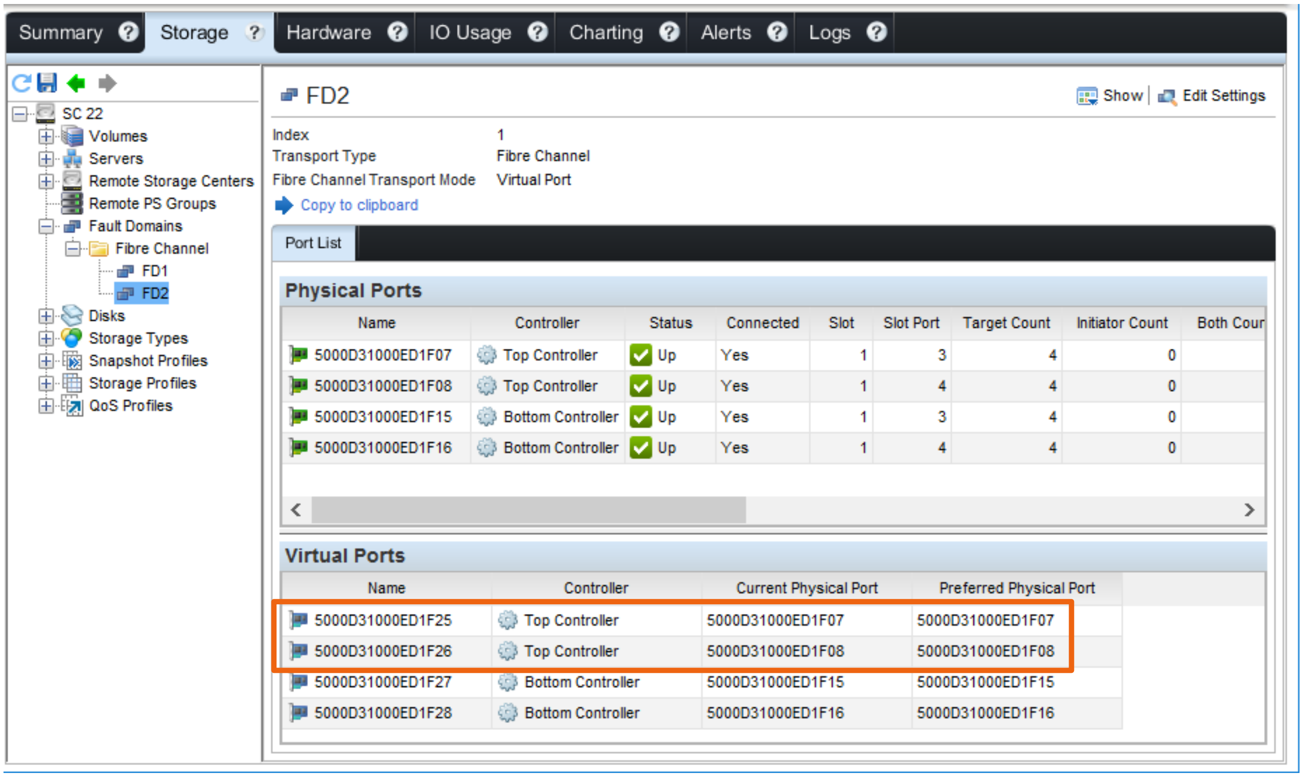
Index	0
Transport Type	Fibre Channel
Fibre Channel Transport Mode	Virtual Port

Physical Ports

Name	Controller	Status	Connected	Slot	Slot Port	Target Count	Initiator Count	Both Cour
5000D31000ED1F05	Top Controller	✓ Up	Yes	1	1	4	0	
5000D31000ED1F06	Top Controller	✓ Up	Yes	1	2	4	0	
5000D31000ED1F13	Bottom Controller	✓ Up	Yes	1	1	4	0	
5000D31000ED1F14	Bottom Controller	✓ Up	Yes	1	2	4	0	

Virtual Ports

Name	Controller	Current Physical Port	Preferred Physical Port
5000D31000ED1F21	Top Controller	5000D31000ED1F05	5000D31000ED1F05
5000D31000ED1F22	Top Controller	5000D31000ED1F06	5000D31000ED1F06
5000D31000ED1F23	Bottom Controller	5000D31000ED1F13	5000D31000ED1F13
5000D31000ED1F24	Bottom Controller	5000D31000ED1F14	5000D31000ED1F14



FD2

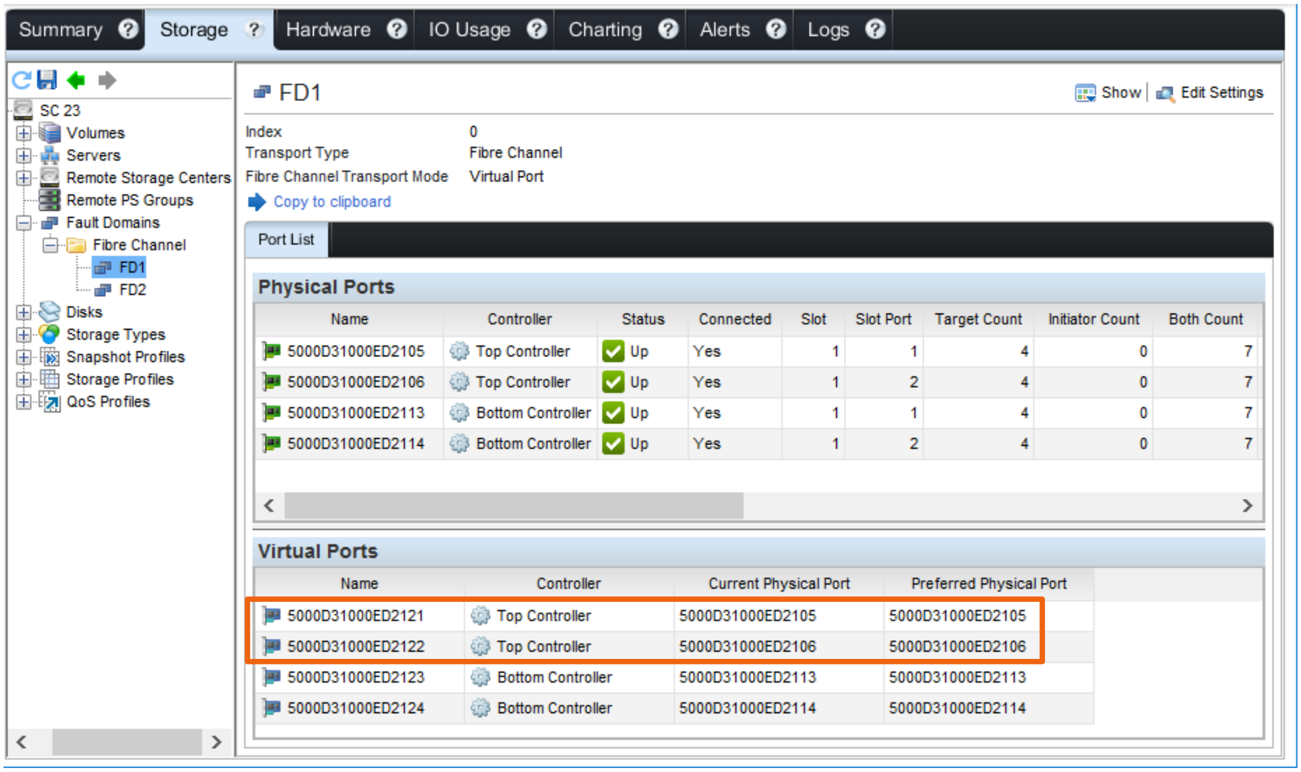
Index	1
Transport Type	Fibre Channel
Fibre Channel Transport Mode	Virtual Port

Physical Ports

Name	Controller	Status	Connected	Slot	Slot Port	Target Count	Initiator Count	Both Cour
5000D31000ED1F07	Top Controller	✓ Up	Yes	1	3	4	0	
5000D31000ED1F08	Top Controller	✓ Up	Yes	1	4	4	0	
5000D31000ED1F15	Bottom Controller	✓ Up	Yes	1	3	4	0	
5000D31000ED1F16	Bottom Controller	✓ Up	Yes	1	4	4	0	

Virtual Ports

Name	Controller	Current Physical Port	Preferred Physical Port
5000D31000ED1F25	Top Controller	5000D31000ED1F07	5000D31000ED1F07
5000D31000ED1F26	Top Controller	5000D31000ED1F08	5000D31000ED1F08
5000D31000ED1F27	Bottom Controller	5000D31000ED1F15	5000D31000ED1F15
5000D31000ED1F28	Bottom Controller	5000D31000ED1F16	5000D31000ED1F16



FD1

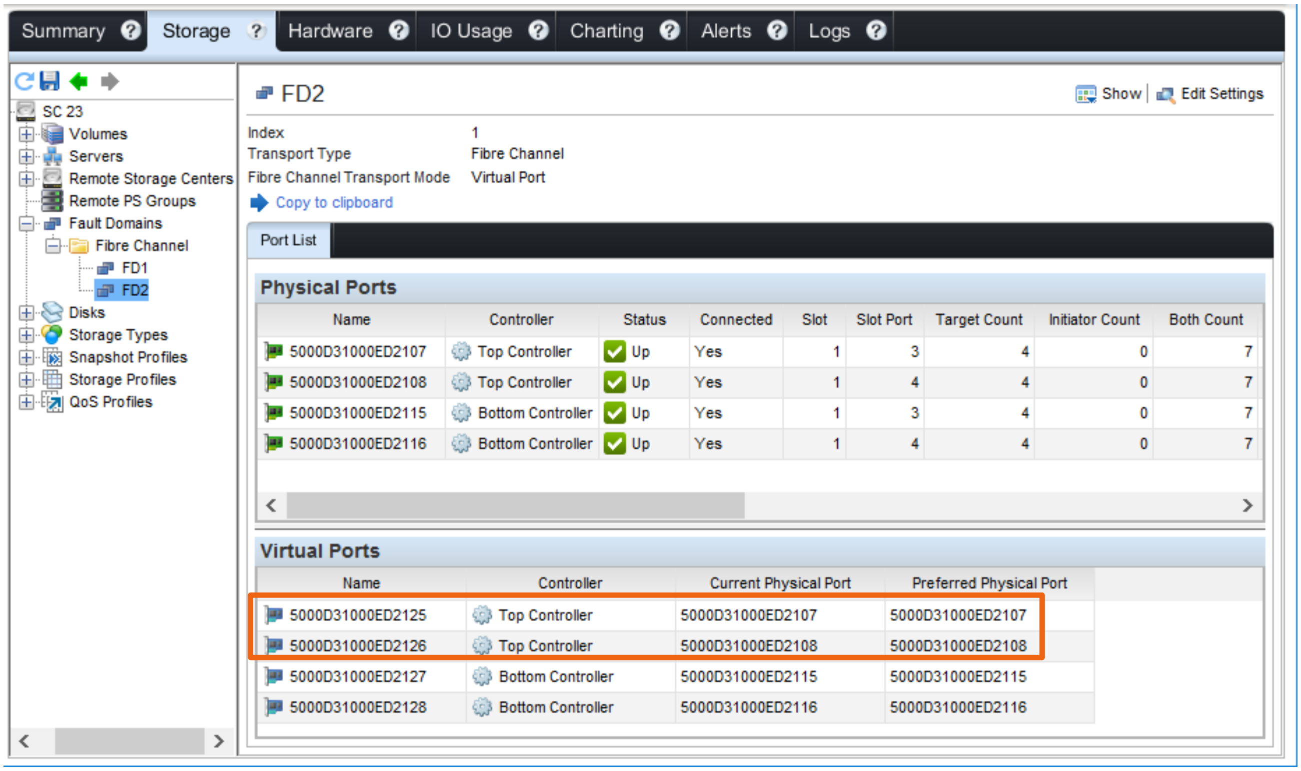
Index	0
Transport Type	Fibre Channel
Fibre Channel Transport Mode	Virtual Port

Physical Ports

Name	Controller	Status	Connected	Slot	Slot Port	Target Count	Initiator Count	Both Count
5000D31000ED2105	Top Controller	✓ Up	Yes	1	1	4	0	7
5000D31000ED2106	Top Controller	✓ Up	Yes	1	2	4	0	7
5000D31000ED2113	Bottom Controller	✓ Up	Yes	1	1	4	0	7
5000D31000ED2114	Bottom Controller	✓ Up	Yes	1	2	4	0	7

Virtual Ports

Name	Controller	Current Physical Port	Preferred Physical Port
5000D31000ED2121	Top Controller	5000D31000ED2105	5000D31000ED2105
5000D31000ED2122	Top Controller	5000D31000ED2106	5000D31000ED2106
5000D31000ED2123	Bottom Controller	5000D31000ED2113	5000D31000ED2113
5000D31000ED2124	Bottom Controller	5000D31000ED2114	5000D31000ED2114



FD2

Index	1
Transport Type	Fibre Channel
Fibre Channel Transport Mode	Virtual Port

Physical Ports

Name	Controller	Status	Connected	Slot	Slot Port	Target Count	Initiator Count	Both Count
5000D31000ED2107	Top Controller	✓ Up	Yes	1	3	4	0	7
5000D31000ED2108	Top Controller	✓ Up	Yes	1	4	4	0	7
5000D31000ED2115	Bottom Controller	✓ Up	Yes	1	3	4	0	7
5000D31000ED2116	Bottom Controller	✓ Up	Yes	1	4	4	0	7

Virtual Ports

Name	Controller	Current Physical Port	Preferred Physical Port
5000D31000ED2125	Top Controller	5000D31000ED2107	5000D31000ED2107
5000D31000ED2126	Top Controller	5000D31000ED2108	5000D31000ED2108
5000D31000ED2127	Bottom Controller	5000D31000ED2115	5000D31000ED2115
5000D31000ED2128	Bottom Controller	5000D31000ED2116	5000D31000ED2116

d) The following relationships can be established after analyzing the information from steps a, b, and c.

Linux multipath device **mpatha** consists of eight storage paths that span across SC 22 and SC 23.

DM-Multipath device	Linux host storage paths	SC Series ports
mpatha	sdb →	SC22, Top Controller, Slot 1, Port 2
	sde →	SC22, Top Controller, Slot 1, Port 4
	sdh →	SC22, Top Controller, Slot 1, Port 1
	sdi →	SC22, Top Controller, Slot 1, Port 3
	sdc →	SC23, Top Controller, Slot 1, Port 1
	sdf →	SC23, Top Controller, Slot 1, Port 3
	sdd →	SC23, Top Controller, Slot 1, Port 2
	sdg →	SC23, Top Controller, Slot 1, Port 4

10.7 Use cases

This section discusses various use cases of Live Volume and synchronous replication with Linux, and highlights technical considerations that should be considered. These use cases are examples and starting points for consideration. They are not a complete list of scenarios in which Live Volume and synchronous replication can be adapted. The scenarios discussed can apply to both single- and multi-site deployments by varying and either scaling the transport mechanisms (LAN, MAN, WAN) connecting site A to site B, or site A to site C.

10.7.1 Single-site

In this single-site scenario, the Linux hosts and SC Series arrays are geographically located within the same site boundaries though different buildings or labs if necessary. Figure 73 depicts this scenario.

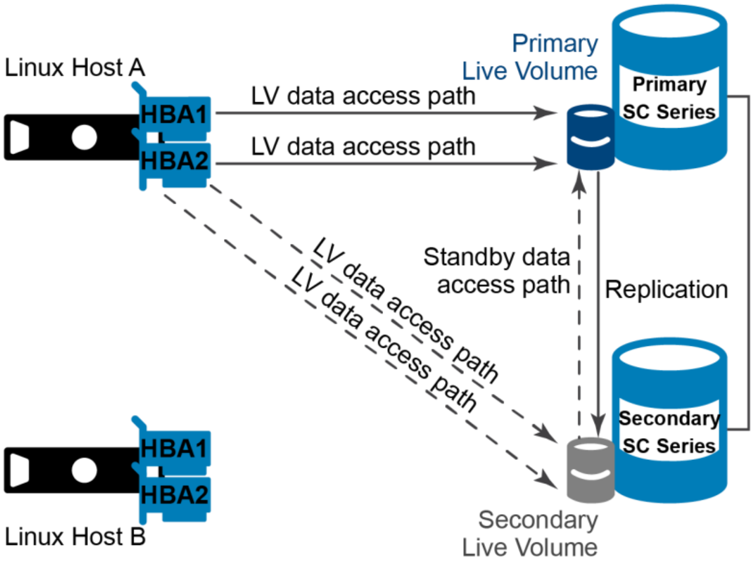


Figure 73 Live Volume in a single-site use case

A volume (or multiple volumes) is first created and mapped to a Linux host. The volumes are scanned, identified and brought into multipath awareness as shown in the following example.

```
[root@tssrv216 ~]# multipath -ll
vol_02 (36000d31000fba60000000000000000015) dm-4 COMPELNT,Compellent Vol
size=10G features='1 queue_if_no_path' hwhandler='0' wp=rw
`-+- policy='round-robin 0' prio=1 status=active
  |- 0:0:0:2  sdd 8:48   active ready running
  |- 1:0:0:2  sde 8:64   active ready running
  |- 0:0:2:2  sdh 8:112  active ready running
  |- 1:0:2:2  sdi 8:128  active ready running
vol_01 (36000d31000fba60000000000000000014) dm-5 COMPELNT,Compellent Vol
size=10G features='1 queue_if_no_path' hwhandler='0' wp=rw
`-+- policy='round-robin 0' prio=1 status=active
  |- 0:0:7:1  sdj 8:144  active ready running
  |- 1:0:10:1 sdk 8:160  active ready running
  |- 0:0:9:1  sdl 8:176  active ready running
  |- 1:0:12:1 sdm 8:192  active ready running
vol_00 (36000d31000fba60000000000000000013) dm-3 COMPELNT,Compellent Vol
size=10G features='1 queue_if_no_path' hwhandler='0' wp=rw
`-+- policy='round-robin 0' prio=1 status=active
  |- 1:0:0:1  sdc 8:32   active ready running
  |- 0:0:0:1  sdb 8:16   active ready running
  |- 0:0:2:1  sdf 8:80   active ready running
  |- 1:0:2:1  sdg 8:96   active ready running
```

These volumes are then converted into Live Volumes and synchronously (either HA or HC modes) replicated to the alternate array. The volumes on the alternate array are then mapped back to the same Linux host. The volumes are once again scanned, identified, and brought into multipath awareness as shown in the following. Each volume is now represented by four additional paths, these paths are the mappings from the alternate array.

```
[root@tssrv216 ~]# multipath -ll
vol_02 (36000d31000fba60000000000000000015) dm-4 COMPELNT,Compellent Vol
size=10G features='1 queue_if_no_path' hwhandler='0' wp=rw
`-+- policy='round-robin 0' prio=1 status=active
  |- 0:0:0:2  sdd 8:48   active ready running
  |- 1:0:0:2  sde 8:64   active ready running
  |- 0:0:2:2  sdh 8:112  active ready running
  |- 1:0:2:2  sdi 8:128  active ready running
  |- 0:0:5:2  sdo 8:224  active ready running
  |- 0:0:8:2  sdq 65:0   active ready running
  |- 1:0:4:2  sdu 65:64  active ready running
  `- 1:0:8:2  sdw 65:96  active ready running
vol_01 (36000d31000fba60000000000000000014) dm-5 COMPELNT,Compellent Vol
size=10G features='1 queue_if_no_path' hwhandler='0' wp=rw
`-+- policy='round-robin 0' prio=1 status=active
  |- 0:0:7:1  sdj 8:144  active ready running
  |- 1:0:10:1 sdk 8:160  active ready running
  |- 0:0:9:1  sdl 8:176  active ready running
  |- 1:0:12:1 sdm 8:192  active ready running
  |- 0:0:5:1  sdn 8:208  active ready running
  |- 0:0:8:1  sdp 8:240  active ready running
  |- 1:0:4:1  sdt 65:48  active ready running
  `- 1:0:8:1  sdv 65:80  active ready running
vol_00 (36000d31000fba6000000000000000013) dm-3 COMPELNT,Compellent Vol
size=10G features='1 queue_if_no_path' hwhandler='0' wp=rw
`-+- policy='round-robin 0' prio=1 status=active
  |- 1:0:0:1  sdc 8:32   active ready running
  |- 0:0:0:1  sdb 8:16   active ready running
  |- 0:0:2:1  sdf 8:80   active ready running
  |- 1:0:2:1  sdg 8:96   active ready running
  |- 0:0:11:1 sdr 65:16  active ready running
  |- 0:0:13:1 sds 65:32  active ready running
  |- 1:0:11:1 sdx 65:112 active ready running
  `- 1:0:13:1 sdy 65:128 active ready running
```

It should be noted that even though these additional paths are shown as active and will be actively used for I/O requests (Round Robin), any I/O requests sent to these paths will be proxied through the replication link to the primary array for commits. The use of these paths would thus introduce unintended latency to any applications that may be latency-adverse; at this time, path priority definitions and grouping (for example, all paths are prio=1 by default and used in equal fashion) are not configurable between Linux hosts and SC Series arrays. Therefore, it is not recommended to use this approach for any critical production use cases.

That being said, this scenario can still apply in certain use cases. In situations where a maintenance event requires SC Series arrays to be powered down, the volumes on the primary array can be Live Volume replicated to an alternate array in a different building or lab. The roles of the arrays can then be swapped, making the alternate array adopt the primary array role (and the paths from them). The latent paths (from the formerly primary array) can then be removed from multipath for the duration of these maintenance events while maintaining uptime and zero disruption to any and all functions and applications that may reside on the Linux hosts. Upon completion of these maintenance events, the volumes and roles of the arrays can then be swapped back or left in place to the discretion of the business requirements.

10.7.2 Multi-site

In this multi-site scenario, the Linux hosts and SC Series arrays are geographically dispersed within a metropolitan (or multi-state) region; sites may be connected with MAN or WAN technologies. Figure 74 depicts this scenario. It should be noted that this scenario can also be scaled down and applied towards single-site deployments as well.

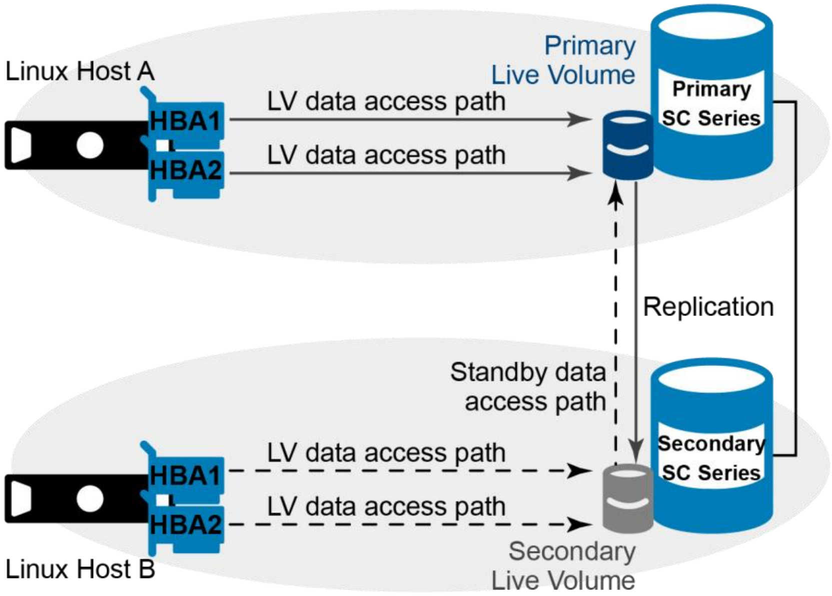


Figure 74 Live Volume in a multi-site use case

The Live Volumes are synchronously (in either HA or HC modes) replicated across SC Series arrays. In this scenario, the alternate array volumes are mapped to a secondary Linux host instead. It should be noted that the volumes mapped to the secondary Linux host are not shared volumes and do not possess shared I/O management and locking mechanisms. These secondary volumes would need to be remounted to reflect any data changes that were written to the primary volumes. For this reason, the integrity of data across both primary and secondary volumes is guaranteed (in either HA or HC modes) as long as the replication link is in a known good state.

The secondary Linux host can be used in various ways including, but not limited to, the following use cases:

- These volumes can be used to present a consistent read-only copy of this data to a remotely located site; this can apply not only for data distribution reasons, but to also manage and minimize any data access latency concerns.
- The consistency of these volumes (and the integrity of the data that it guarantees) also lends itself towards database replication use. Databases (and applications) can be brought online at the remotely-located site, in either read-only mode or used in a disaster recovery after the roles of the SC Series arrays are swapped (the secondary array becomes the primary array).
- These volumes can also be used to complement virtualization technologies such as Red Hat Enterprise Virtualization (RHEV) to allow for the replication of virtual machine workgroups from one site or hypervisor to another site or hypervisor. RHEV hosts its virtual machines on a storage domain that in turn is correlated through a one-to-many relationship to one or multiple backing SC Series volumes. These volumes are enabled with Live Volume or are synchronously replicated to an alternate site or secondary array. At the alternate site, these storage volumes can then be used to

reconstruct or import the storage domain into the alternate data center object, and from which object, reconstruct the virtual machine workgroup.

The following technical and performance considerations should be taken when exploring these use cases.

/etc/multipath.conf: This keeps the contents of /etc/multipath.conf file consistent across all hosts sharing these Live Volumes; this file contains the definitions of volume WWIDs and their respective aliases and will ensure that volumes are identified across the different hosts as the same device, and contain the same data to maintain application integrity.

/etc/fstab: Use the /etc/fstab file in conjunction with /etc/multipath.conf to ensure that volumes are accurately mounted to their respective and proper mount points in the filesystem. Use the multipath device aliases (if defined) or default multipath device naming (mpathX) in /etc/fstab to maintain this consistency.

/etc/ntp.conf: Always use the /etc/ntp.conf file to maintain a certain degree of time-based integrity across all infrastructure. The use of /etc/ntp.conf file becomes even more critical when attempting to maintain data integrity across multiple cluster nodes/sites dispersed across larger geographic deployments (MAN, WAN).

Cluster configurations: In addition to the considerations mentioned above, take into account cluster-specific configuration files as well and the best practices of their respective vendors. The discussion of cluster-specific configuration remains outside the scope of this paper. The list of enterprise-class clustering technologies include but is not limited to Red Hat Cluster Suite, IBM® PowerHA®, Oracle® Solaris Cluster, Oracle RAC, HP-UX ServiceGuard, and Symantec™ Veritas™ Cluster Server to name a few.

Performance considerations: It should be noted that the dual commit nature of synchronous replication (I/O writes must be committed to the secondary SC Series volume before it is committed to the primary volume) may introduce latency to the applications generating these write requests. The use of synchronous replication guarantees the consistency and integrity of the data at both SC Series sites when the acknowledgment is received by the requesting application. The use of synchronous replication should be made upon the detailed and thorough analysis and understanding of the applications and its I/O needs.

The following demonstration has a small dataset (40 MB) that is written to a primary Live Volume and is synchronously replicated to an alternate array. The filesystem is formatted as ext4 and mounted (@ /vol_00) with the discard and sync (the sync option disables filesystem buffer caching) flags.

```
[tssrv216:/root]# cd /etc; time tar cvf - . | (cd /vol_00; tar xvf -)
[snip]
real    0m24.147s
user    0m0.122s
sys     0m1.421s
```

In this next demonstration, the synchronously replicated Live Volume at the alternate site is mounted to the secondary Linux host and writes are applied to the secondary Linux host. This demonstrates additional latency as all write I/O requests are proxied through the secondary SC Series array to the primary array for processing.

```
[tssrv217:/root]# cd /etc; time tar cvf - . | (cd /vol_00; tar xvf -)
[snip]
real    0m30.864s
user    0m0.111s
sys     0m1.422s
```

In this final demonstration, the replication link is quickly changed from synchronous replication to asynchronous replication and write I/O requests are applied to the primary Live Volume. Note the reduction in time required to commit these writes compared to the previous use of synchronous replication.

```
[tssrv216:/root]# cd /etc; time tar cvf - . | (cd /vol_00; tar xvf -)
[snip]

real    0m18.266s
user    0m0.104s
sys     0m1.328s
```

10.7.3 Multi-site with LVMR

In this alternate multi-site scenario, the Linux hosts and SC Series arrays are geographically dispersed within a metro (or multi-state) region. Sites may be connected through MAN or WAN technologies. Additionally, a third site has been included using the LVMR feature of SC Series storage. Figure 75 depicts this scenario. It should be noted that this scenario can also be scaled down and applied towards single-site deployments as well.

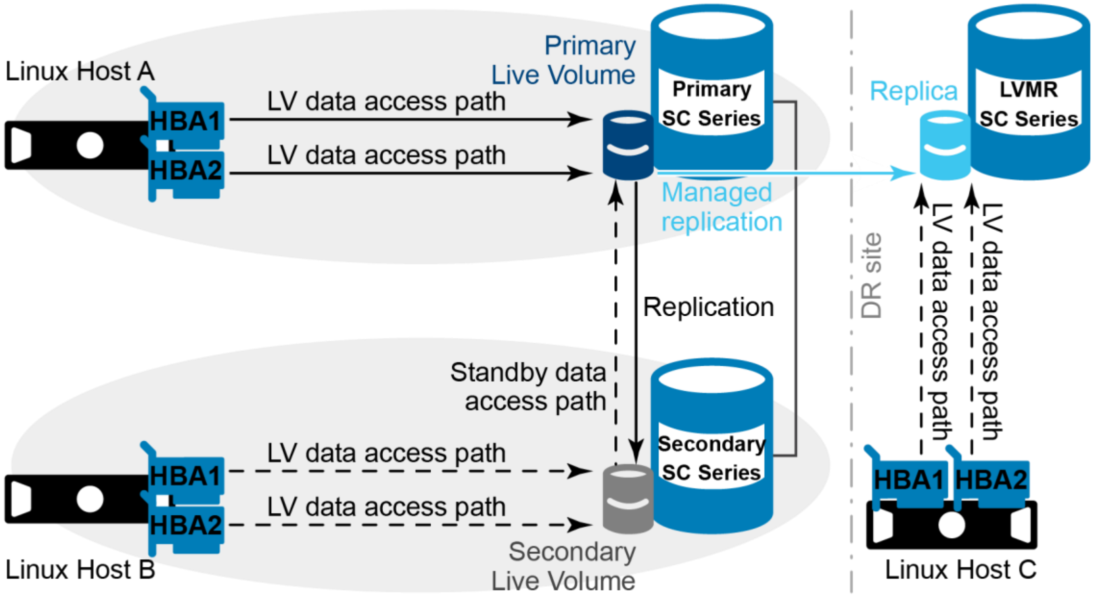


Figure 75 Live Volume in multi-site use case with LVMR

The third site and data in this scenario is replicated asynchronously. One of its uses may include the remotely located disaster recovery copy of business-critical data. It should be noted that the LVMR copy is always associated or paired with the primary SC Series array. If the primary and secondary array roles are swapped, the LVMR copy automatically transfers and associates or pairs itself with the array that assumes the primary role. Additionally, this asynchronously replicated copy (unlike a synchronously replicated) is current if the replication link has sufficient bandwidth and the Replicate Active Snapshot (Replay) feature is enabled, or current as of the last captured snapshot if the feature is disabled. Consequently, discussions should also be conducted around acceptable RPO and RTO thresholds and maintaining agreeable SLAs with all business entities involved.

The technical considerations discussed in the section 10.7.2 should be kept in consideration when setting up this use case.

11 Live Volume use cases

This section exhibits additional examples of how Live Volume can be used in a variety of environments. Live Volume is not limited to these use cases.

11.1 Zero-downtime SAN maintenance and data migration

With Live Volume, maintenance activities can be performed without downtime on an SC Series array. This includes tasks such as taking an array offline to move its location, perform service-affecting enclosure or disk firmware updates, and migrate the volume to a new SAN.

The requirements for this operation include:

- MPIO installed and appropriately configured on the host computers
- Server(s) properly zoned into both SC Series arrays
- Server(s) configured on both arrays
- At least a 1 Gb low-latency replication link between arrays

Summary: In advance of a planned outage, Live Volume can non-disruptively migrate volumes from one SC Series array to another, enabling continuous operation for all applications — even after one array has completely powered down.

Operation: In an on-demand, operator-driven process, Live Volume can transparently move volumes from one SC Series array to another. The applications operate continuously. This enables several options for improved system operation:

- Redefine remote site as primary for all volumes on local site
- Shut down local site
- Reverse process after planned outage is completed

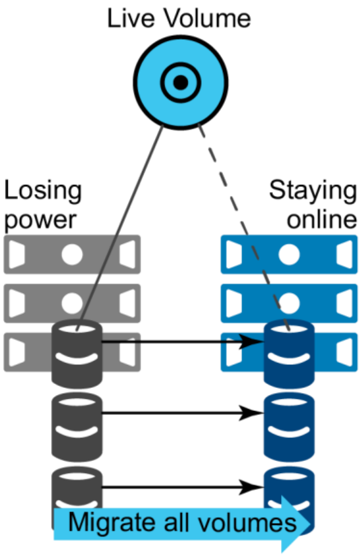


Figure 76 Maintaining availability of applications and services during scheduled maintenance

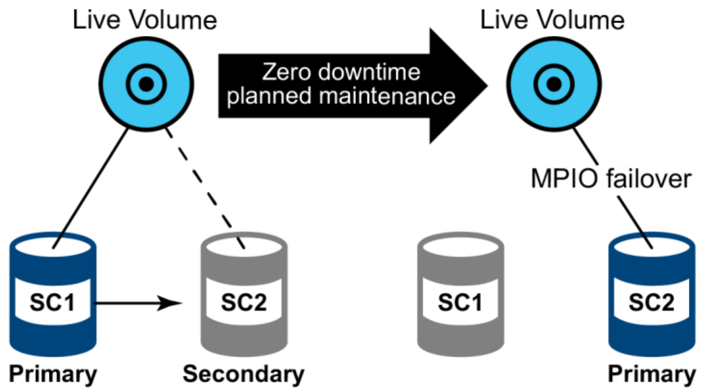


Figure 77 Applications remain continuously available on SC2 while SC1 undergoes maintenance

11.2 Storage migration for virtual machine migration

As VMware, Hyper-V, or XenServer virtual machines are migrated from data center to data center, Live Volume can automatically migrate the related volumes to optimize performance and minimize I/O network overhead.

Live Volume continuously monitors for changes in I/O traffic for each volume and non-disruptively moves the primary storage to the optimal SC Series array for optimum efficiency. This involves the following:

- Migrate the virtual machine using the server virtualization software.
- Live Volume will track the changes in I/O traffic mapping and will perform a primary/secondary swap after a fixed amount of time and data have been transferred.

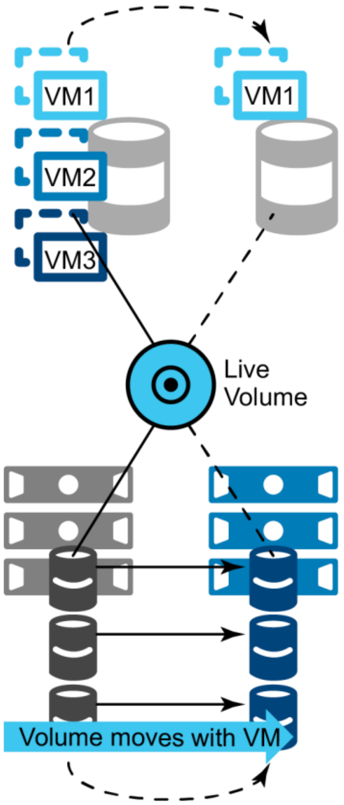


Figure 78 Storage follows the application (server virtualization)

The requirements for this operation include the following:

- Server(s) properly zoned into both SC Series arrays
- Server(s) configured on both arrays
- Stretched Layer 2 networking between source and destination sites or hypervisors
- 1 Gbps or better low-latency iSCSI or Fibre Channel connectivity between the arrays to support asynchronous or synchronous Live Volume replication

11.3 Disaster avoidance and disaster recovery

In anticipation of an outage (for instance, an approaching hurricane) or after an unplanned outage has occurred, Live Volume migrates data and applications to recovery systems. Live Volume used in this manner can prevent data loss and application downtime.

Operation: Live Volume can transparently move volumes from one SC Series array to another. The applications operate continuously. This enables several options for improved system operation:

- Redefine remote site as primary for all volumes on local site
- Shut down applications on local site
- Restart or recover applications on remote site
- Move applications seamlessly back to their original locations using Live Volume

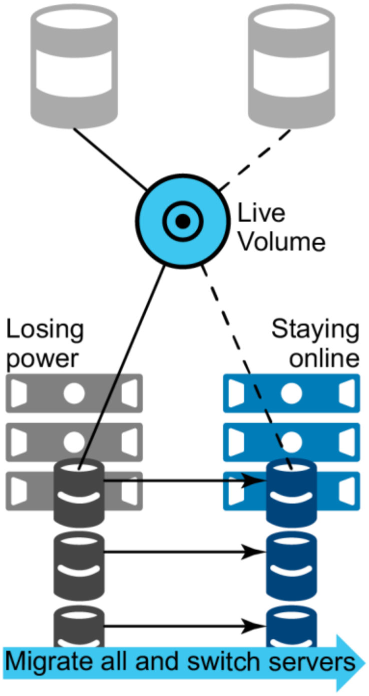


Figure 79 Disaster avoidance and disaster recovery

11.4 On-demand load distribution

In this use case, Live Volume transparently distributes the workload, balances storage utilization, or balances I/O traffic between two SC Series arrays.

Configuration: SC Series arrays must be connected using high-bandwidth and low-latency connections, especially when synchronous replication is used with Live Volume.

Operation: In an on-demand, operator-driven process, Live Volume can transparently move volumes from one SC Series array to another. The applications operate continuously. This enables several options for improved system operation:

- Distribution of I/O workload
- Distribution of storage
- Distribution of front-end load traffic
- Reallocation of workload to match capabilities of heterogeneous systems

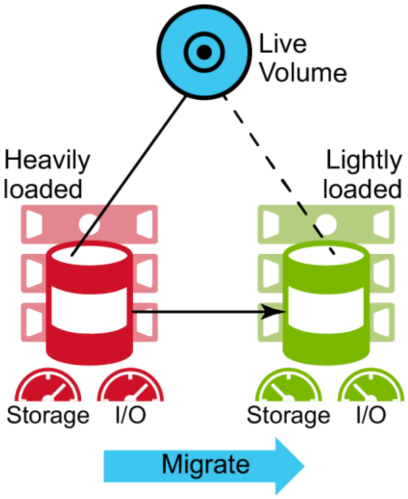


Figure 80 On-demand local distribution

11.5 Cloud computing

In this use case, Live Volume transparently distributes the workload, balances storage utilization, or balances I/O traffic between multiple SC Series arrays within a data center, enabling continuous flexibility to meet changes in workload and to provide a higher-level system up time.

Configuration: Live Volumes can be created between any two SC Series arrays in a data center. Each array can have many Live Volumes, each potentially connecting to a different array.

Operation: In an on-demand, operator-driven process, Live Volume can transparently move volumes from one SC Series array to another. The applications operate continuously. This enables several options for improved system operation:

- Distribution of I/O workload
- Distribution of storage
- Distribution of front-end load traffic
- Reallocation of workload to match capabilities of heterogeneous systems

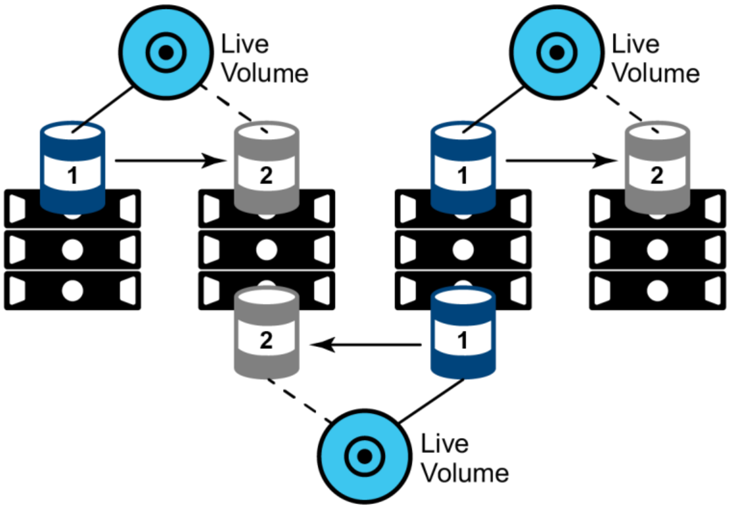


Figure 81 Cloud computing

11.6 Replay Manager and Live Volume

Replay Manager and Live Volume are mutually exclusive features that cannot be used together. If storage hosts are split between data centers in a stretched cluster configuration using Live Volume, then Replay Manager cannot be used to create application-consistent snapshots.

A Technical support and additional resources

Dell.com/support is focused on meeting customer needs with proven services and support.

Storage solutions technical documents and videos provide expertise that helps to ensure customer success on Dell EMC storage platforms.

A.1 Related resources

- Dell EMC SC Series Best Practices with VMware vSphere
- Dell EMC SC Series Best Practices with VMware Site Recovery Manager
- Dell SC Series Storage and Microsoft Hyper-V
- Dell EMC SC Series Storage and Microsoft Multipath I/O
- Dell EMC SC Series with Red Hat Enterprise Linux 6x
- Dell EMC SC Series with Red Hat Enterprise Linux 7x
- Red Hat Enterprise Linux 6 DM Multipath Configuration and Administration
- Red Hat Enterprise Linux 7 DM Multipath Configuration and Administration
- VMware vSphere 6.0 Metro Storage Cluster Recommended Practices
- Live Volume with Auto Failover Support for Microsoft (three-part video series)
- Dell EMC Storage Compatibility Matrix