

# VMware Virtual Machine Protection Using Transparent Snapshots

## Abstract

This white paper provides insights on how to protect and restore VMware virtual machines using transparent snapshots, available with Dell PowerProtect Data Manager.

October 2022

## Revisions

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## Acknowledgments

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## Executive summary

This white paper provides insights on how to protect and restore VMware virtual machines using transparent snapshots, available with Dell PowerProtect Data Manager. This document details the architecture and life cycle of transparent snapshots and describes how this new capability integrates with PowerProtect Data Manager. It also includes an overview of the process for restoring VMs, and presents test results that show the performance benefits of this solution.

# 1 Introduction

The VMware virtual machine backup process transfers or exports data from a virtual machine (VM) within a VMware environment to a secondary protection storage system. This system, such as a Dell PowerProtect appliance, can be on a primary or secondary site, or on the cloud. A backup engine or software such as PowerProtect Data Manager manages this process. PowerProtect Data Manager can perform data- and copy-management operations on the backup copies and ensure that all data is cataloged properly. This function makes available a consistent VM copy as part of a restore requirement in a disaster scenario.

PowerProtect Data Manager can protect VMware virtual machines in a reliable and efficient manner using VMware API for Data Protection (VADP) snapshots (see Figure 1). These VADP snapshots are reliable, proven, and certified by VMware, and can be used as part of backup operations.

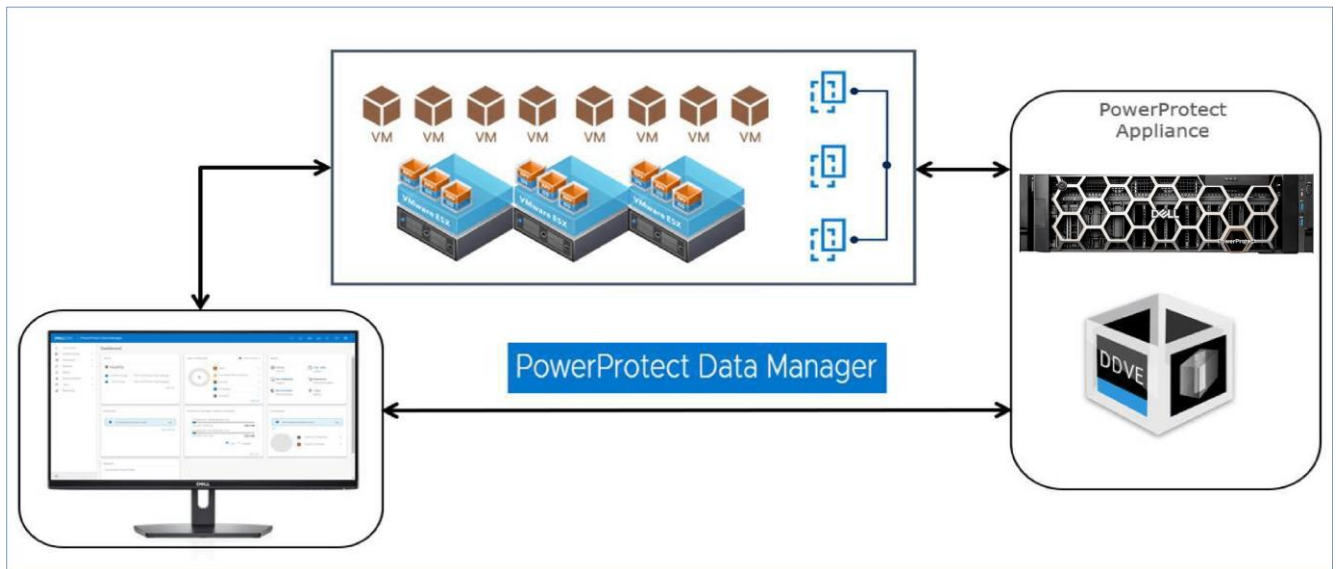


Figure 1 PowerProtect Data Manager for VMware

However, the VADP snapshot process pauses the execution of the VM and allows in-flight disk I/Os to complete. This action may increase the read and write latency and affect the snapshot and VM ecosystem life cycle. When analyzing the life cycle of VADP snapshot, the snapshot entry and exit points inflict a penalty on a VM. After producing a snapshot of a VM disk file, requiring the VM to be stunned, a snapshot of the VM disk file is ingested. Then, the deltas must be consolidated into the base disk. When you create a snapshot of a high-transactional application, like a database, there can be adverse effects. These effects include lengthy backup windows and application timeouts when the stun to ingest and consolidate the workflow is not efficiently managed.

Addressing these issues requires a solution which can deliver not only backup and restore capabilities, but also an alternative way to reduce the adverse effects of the VM stun operation.

## 2 Transparent snapshots architecture

As represented in Figure 2, PowerProtect Data Manager transparent snapshots use the vSphere API for I/O (VAI/O) Filtering framework. The transparent snapshots data mover (TSDM) is deployed in the VMware ESXi infrastructure through a PowerProtect Data Manager VIB. This deployment creates consistent VM backup copies and writes the copies to the protection storage (PowerProtect appliance).

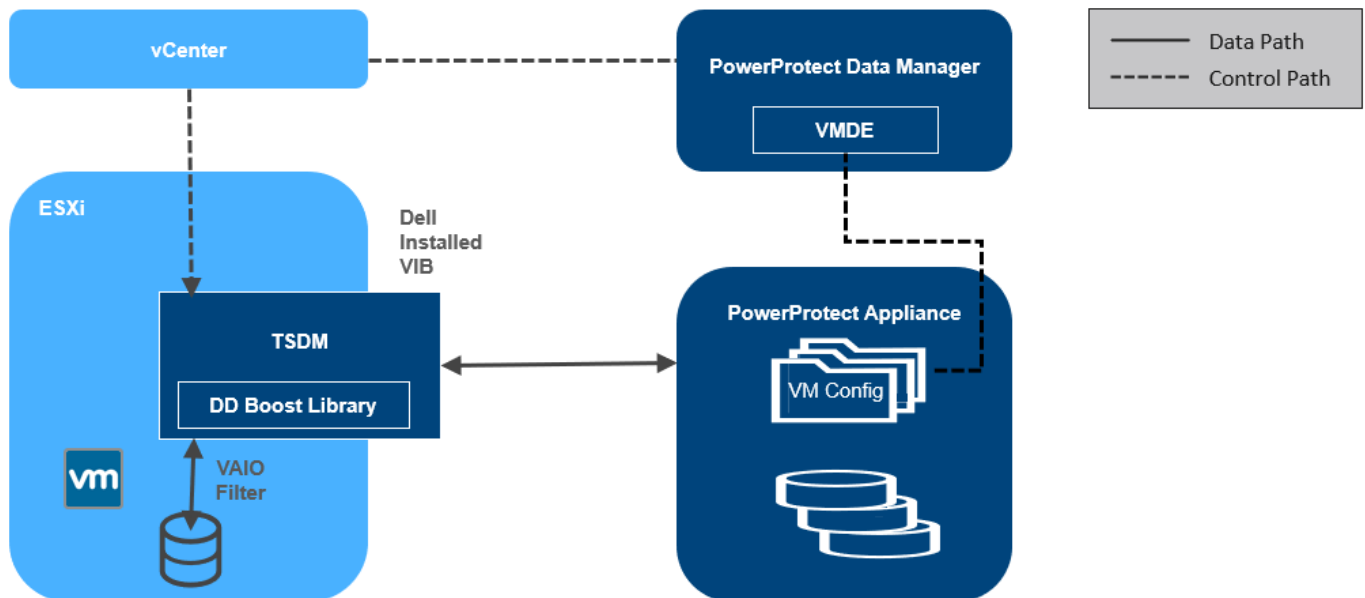


Figure 2 Transparent snapshots architecture

The following points describe the components to provide you with an understanding of the control and data path as represented in Figure 2:

- PowerProtect Data Manager assumes the role of an orchestrator where it identifies the VM assets in the VMware environment and provides scheduling capabilities.
- PowerProtect Data Manager uses VM Direct Engine to communicate with the VMware vCenter level APIs provided by VMware. The VM Direct Engine communicates with vCenter to achieve the following two key tasks:
  - Creates and tracks the progress of the vCenter level tasks that are visible to the end users such as sync, restore, and snapshot operations
  - Responsible for locating the relevant ESXi host on which the operation (backup or restore) is to be performed, based on the placement of the VM asset to be protected
- On each ESXi host, the protection-related APIs and workflows from VMware are facilitated using a VAIO filter.
- Each ESXi communicates with Transparent Snapshot Data Mover (TSDM) component, which is responsible for the VM-backup data movement.
- The backup and restore processes transfer the transparent snapshots respectively to and from the PowerProtect Appliance.

- TSDM also consists of the PowerProtect Appliance SDK (DDBoost Library) which helps the framework access the storage units on the PowerProtect Appliance. It also helps write and read data from those storage units.

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**Note:** PowerProtect Data Manager manages the TSDM component by using the VIB (VMware Certified) from Dell Technologies. This component is installed dynamically as part of the integration of PowerProtect Data Manager that requires protection of VMs using transparent snapshots. The APIs being used are supported in VMware ESXi 7.0 U3 and later.

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### 3 Integration with PowerProtect Data Manager

This section examines the steps to integrate PowerProtect Data Manager within the VMware infrastructure, including deploying all necessary components and enabling VM protection using transparent snapshots.

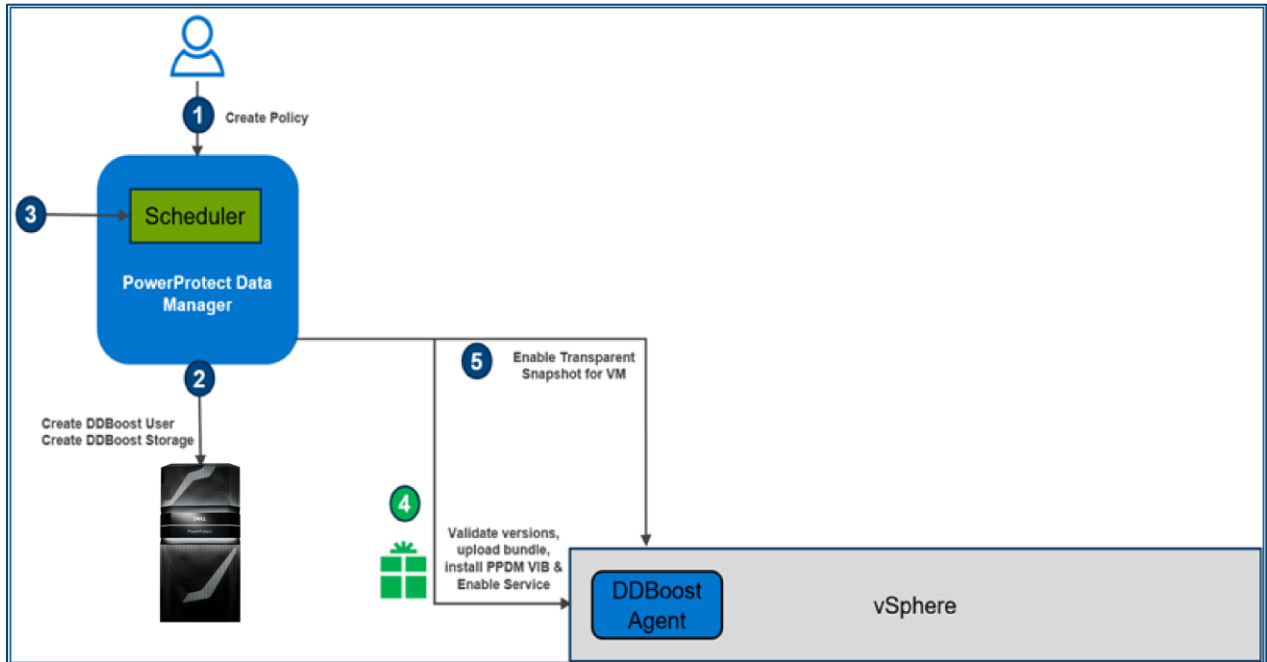


Figure 3 Integration with PowerProtect Data Manager

1. When the VMware VMs have been discovered as PowerProtect Data Manager assets, the next step is to create a protection policy and add the VM assets for protection.

**Note:** The criteria for policies to be eligible for transparent snapshots is listed in section 3.1

2. PowerProtect Data Manager creates the Storage unit in the PowerProtect appliance for storing backups.
3. According to the schedule defined in the Protection Policy, the scheduler activates.
4. As these steps occur, the PowerProtect Data Manager VM Direct Engine initiates API calls to vCenter. Then, it validates the ESXi version (7.0U3 and later), uploads it, installs the PowerProtect Data Manager VIB, and enables the service. Then, the VAIO filter is attached to each VM disk. In this step, the TSDM component is created but remains idle (running but not used) because there is no data movement. You can see the VIB file installed on the ESXi host that houses the VM being protected (Figure 4).

Summary							
VIB Name	:	tsdm					
VIB Operation	:	vib_install					
vCenter	:	VC					
Hosts Managed	:	esxi03.tme.local					

<input type="checkbox"/>	DEL_bootbank_tsdm_19.9.0-10EM.703.0.0.17990185.v...	4,201.92 ..	07/01/2021, 3:03:22 PM	File	[esxi03_DS1] DEL_bootbank
<input type="checkbox"/>	metadata.zip	3.52 KB	07/01/2021, 3:03:22 PM	File	[esxi03_DS1] metadata.zip

Figure 4 The VIB file installed

5. When vCenter acknowledges success, PowerProtect Data Manager marks the VM to be protected by transparent snapshots.



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**Note:** Aside from the DEL\_bootbank VIB file, Figure 4 shows a metadata.zip file that contains information related to the VIB, such as dependencies on the host, system requirements, summary, and version. The files are in the Datastore Files section of the ESXi host. This VIB installation is also shown in the PowerProtect Data Manager Policy Config Job summary.

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## 3.1 Criteria

The criteria for policies to be eligible for transparent snapshots are as follows:

- 1) Crash Consistent
- 2) Performance Optimization mode or Capacity Optimization Mode (with PowerProtect Data Manager version 19.10 and later)
- 3) Swap File Exclusion: Disabled
- 4) Quiesce Filesystem: Disabled

Policies that have created before PowerProtect Data Manager 19.9 will not automatically start to use TSDM upon upgrade to 19.9 and later. The same goes for policies created in 19.9 or earlier with Capacity Optimization mode, TSDM will not be used automatically upon upgrade to PowerProtect Data Manager 19.10. The Data Mover type would be updated next time the policy is edited or when it is explicitly configured. When a full backup would be performed the first time, TSDM operates then as well as when the policy option is switched between Performance and Capacity Modes. TSDM remains the Data Mover when Performance Optimization mode is switched to Capacity Optimization mode and conversely.

## 3.2 PowerProtect Data Manager 19.10 enhancements

As a precautionary measure, starting with version 19.10, PowerProtect Data Manager uses VADP automatically in the following cases:

- VM with RDM disks
- VM with encrypted VMDKs
- VM with more than 40 disks
- VM with Fault Tolerance (FT) enabled

Also, with PowerProtect Data Manager 19.10, backups that are taken with TSDM as the data mover can replicate to the cloud using Cloud DR for all supported cloud protection and recovery use cases.

## 3.3 PowerProtect Data Manager 19.11 enhancements

The PowerProtect Data Manager UI starting with version 19.11 provides an option to override the automatic protection engine selection and manually select the VM Direct protection engine to be used. It also enables the option to migrate protection engine being used on an asset basis. For example, VADP is being used to backup a certain VM and now the backup admin would like to leverage TSDM so the asset protection engine can be migrated to TSDM.

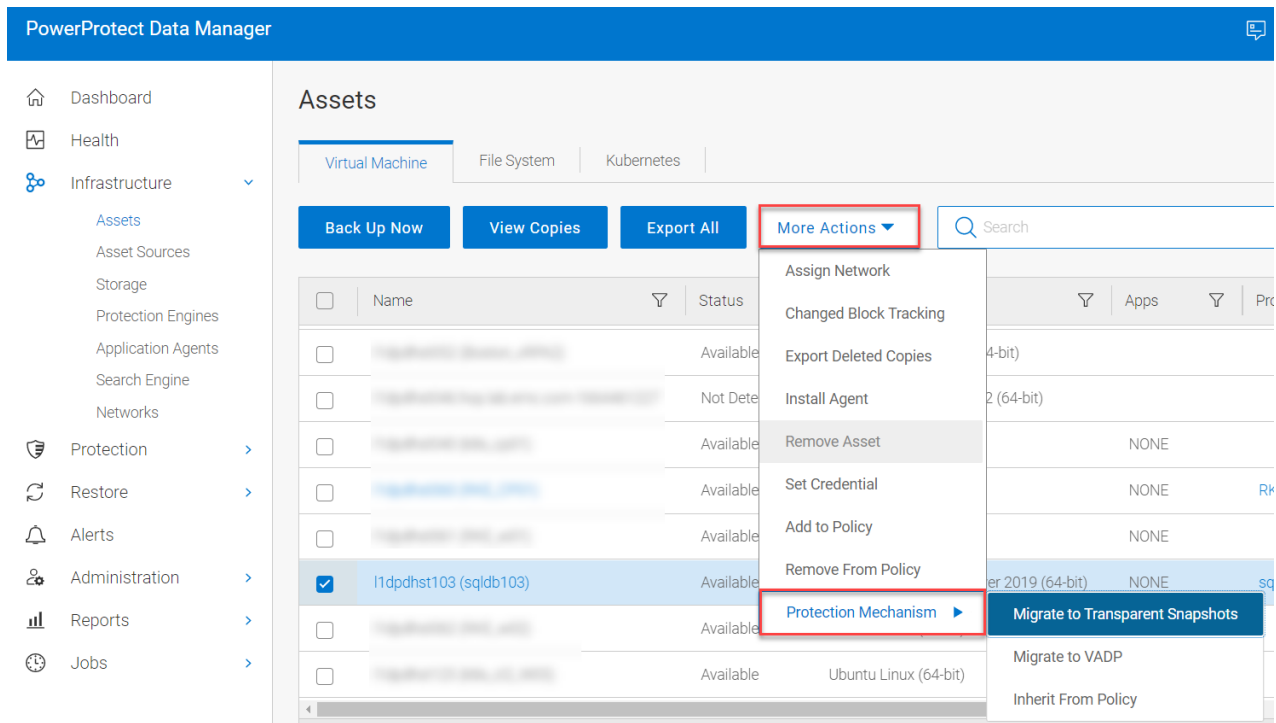


Figure 5 Protection Mechanism override

### 3.4 PowerProtect Data Manager 19.12 enhancements

The following features and changes were introduced in version 19.12:

- 1) The number of concurrent TSDM jobs are doubled to 20 for both backup and restore per ESXi host. In previous releases, the maximum backup and restore jobs were 10 for each type. This new throttling mechanism is available with PPDm 19.12 and vSphere 7.0U3d and later.
- 2) VIB deployment enhancements:
  - The VIB deployment process will now operate on the relevant ESXi hosts concurrently - 25 ESXi hosts at a time
  - The VIB deployment process skips ESXi hosts which are powered off or in maintenance mode
  - The VIB deployment process has been enhanced to prevent upload of the VIB package to hosts that already have the package in one of their datastores

## 3.5 Network considerations

TSDM requires connectivity to Data Domain for data path purposes (see various flows in [Section 4](#) below). This communication is facilitated using VMKernel ports on the ESXi hosts where the TSDM VIB is installed. The transparent snapshots solution would work outside of the box without dedication of VMKernel ports as any VMKernel port that can communicate with Data Domain would be automatically used.

That said, for optimal predicted performance and scale, it is highly recommended to adhere to the following guidelines:

- 1) **Dedicated VMKernel Ports:** Create a single dedicated VMKernel port per ESXi host. Having a dedicated VMK would decrease the chances of performance degradation due to sharing of VMKernel ports with other consumers, especially vMotion and vSAN.
- 2) **VMKernel Ports Placement:** We recommended placing the VMK on VLAN dedicated for TSDM to PowerProtect DD traffic or a VLAN dedicated for backup traffic. It is advised that the VMK ports and the relevant Data Domain ports would be on the same L2 network (same broadcast domain). Avoid placing the VMKs and Data Domain Ports on VLANs with heavy burst traffic such as vMotion, iSCSI networks, or FT.
- 3) **Consistent End-to-End MTU:** Ensure the MTU set on the VMKernel port and on the PowerProtect DD port is uniform from end to end. You can validate this setting using the ESXCLI command **vmkping** with the DF flag. For example, the following command would check that there is a uniform end-to-end jumbo frame through a specific VMK port: **vmkping -l vmk1 -d -s 8972 10.10.100.1**

## 3.6 vProxy considerations

The embedded vProxy runs on PowerProtect Data Manager itself and it is available for TSDM operations without having to perform any specific configuration. The embedded vProxy for TSDM supports a single vCenter and up to 180 concurrent VM backups. The embedded vProxy is suitable for nearly all TSDM use cases and scale requirements. That said, it is important to note that external vProxies are required for TSDM only when there is more than a single vCenter on the same PPDM instance, and there is more than one vCenter with VM workload to be protected using TSDM.

## 4 Transparent snapshots life cycle

Transparent snapshots provide for a simple, fast, and efficient VM backup that is outlined using the following life cycle:

- Monitor: Track delta changes in memory
- Process: Transfer delta changes directly to protection storage
- Release: Remove delta table and any temporary data blocks

To provide a better understanding of the VM backup process, this section describes the synchronization and data transfer process which consists of four major steps:

- Full sync
- Transparent Snapshot creation
- Delta sync
- Snapshot retire

### 4.1 Full sync operation

1. During a full sync operation (see Figure 6), PowerProtect Data Manager issues a full sync request. This request includes all required parameters such as VM information and disk inclusion and exclusion details.
2. PowerProtect Data Manager queries vCenter to locate the relevant ESXi host, and the operation is transferred to the ESXi host.
3. The ESXi syncs with the TSDM component uses VAIO, and makes the TSDM aware that a full sync should be performed on the specific asset.
4. The TSDM first uses VAIO to read and query the allocated areas of the disks. After resolving the allocated areas, the TSDM starts to read the data.
5. The TSDM also uses the DDBoost library to establish a connection to the PowerProtect appliance. Empty files are created in the secondary storage (each file corresponding to the flat VMDK file of the VM asset), and the data transfer begins. Eventually, all allocated areas are transferred and written to the PowerProtect appliance.
6. When the full sync operation is complete, the TSDM sends an acknowledgment to the ESXi host. vCenter marks the task as complete.

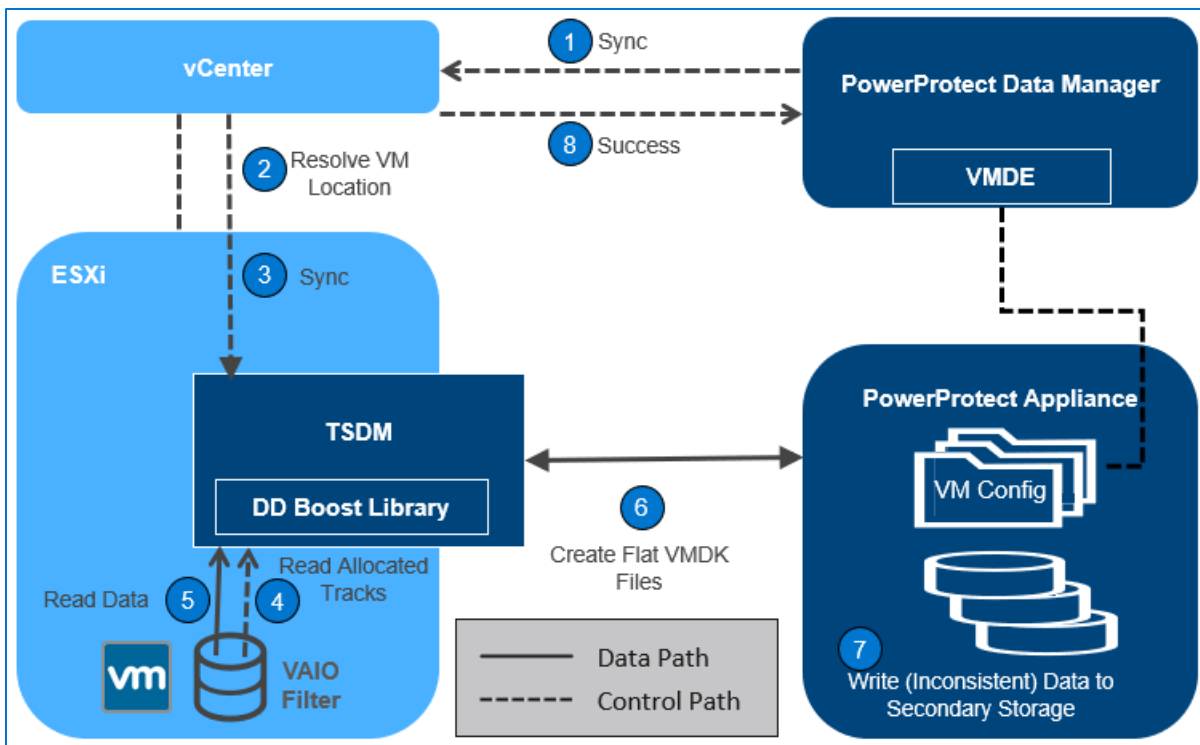


Figure 6 Full sync operation

**Note:** Because files created during the full sync flow are inconsistent, you cannot use them to restore the VM to a consistent point in time. That reason is because during the full sync flow, the VM still serves I/Os, and data in disks might change during the full sync operation itself. A delta sync operation must be performed right after the full sync operation, which creates a consistent point-in-time copy that can be used later for a restore operation.

## 4.2 Transparent snapshots creation

1. After the full sync is complete, PowerProtect Data Manager issues a snapshot creation operation (see Figure 7).
2. PowerProtect Data Manager requests a sync operation against vCenter.
3. The API calls are passed to the ESXi host after the location is resolved. In this step, the TSDM has no active role because no data transfer occurs.
4. The ESXi host communicates with the relevant VM asset using VAIO, and the snapshot is persisted to the Snapshot Extent Store (SES).

**Note:** The Snapshot Extent Store (SES) is dynamically created during snapshot creation and is deleted when the snapshot is retired. The SES stores the bitmaps that correspond to the data in the disk at that time. The SES uses thin-allocated space across the overall datastore space and does not affect the specific VM quota.

5. Using the SES, the VAIO filter takes the bitmap in memory and saves it. Because all of it is bitmap based, creating the transparent snapshot is fast, which reduces the read/write latency.
6. After the bitmap is persisted, the filter can start tracking changes on the disk again, using a new bitmap.
7. The snapshot operation is marked as finished. PowerProtect Data Manager can use the VM Direct Engine to access the vCenter level task completion and get the snapshot UUID that was created.

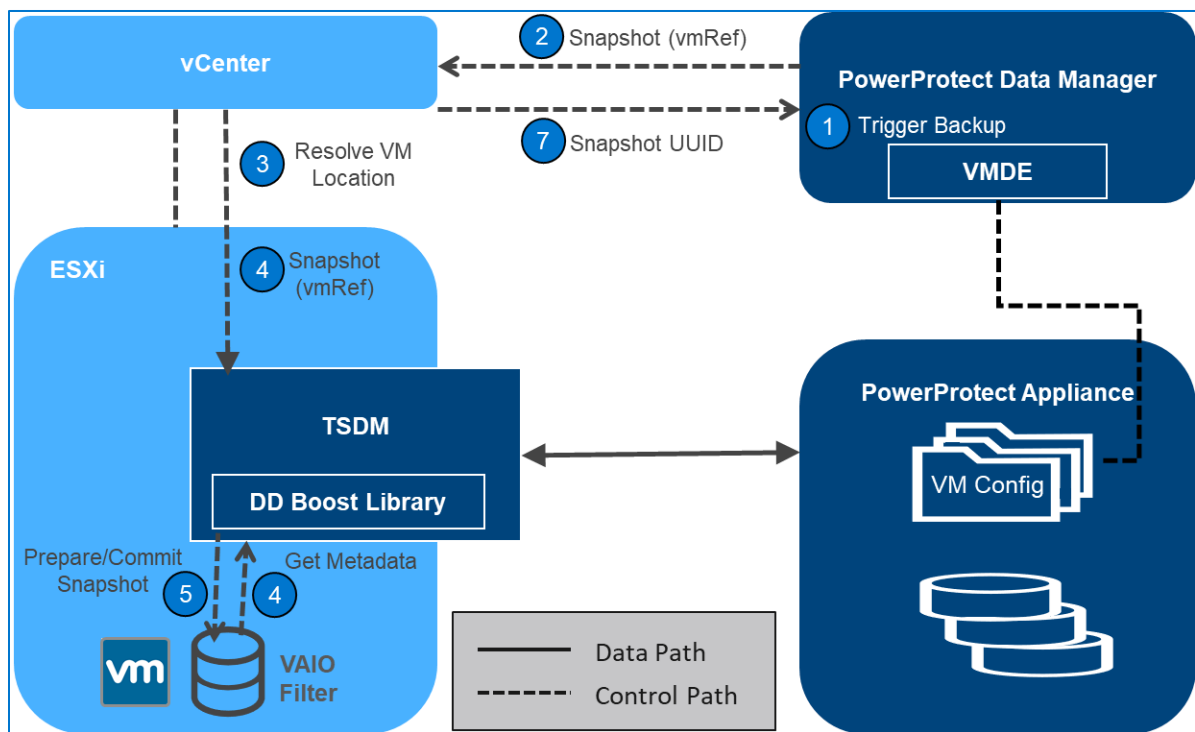


Figure 7 Transparent Snapshot creation

### 4.3 Delta sync operation

1. After the transparent snapshot creation operation is complete, you can initiate a delta sync operation or an incremental operation (see Figure 8). PowerProtect Data Manager issues API calls to vCenter for a delta sync operation and provides the snapshot UUID that was created in the previous step.
2. PowerProtect Data Manager signals to TSDM to start the delta sync flow through vCenter API which resolves the relevant ESXi host.
3. The TSDM uses VAIO APIs to query and track the changed areas that the Transparent Snapshot bitmap represents.
4. For each changed area, the data is read from the disk.

**Note:** The delta sync operation uses a Fast Copy overwrite approach. In this approach, the previous point-in-time files are first fast copied. The fast-copied files are partly overwritten with the incremental data. Only the delta or changes that are represented by the currently synced snapshot are copied. These changes are copied in the Snapshot Extent Store (SES).

5. The changed data or delta is read from the disks to create a consistent data flow.
6. The read data is now written to protection storage using the DDBoost Library.
7. The changed data write to protection or secondary storage is now complete.
8. When all data has moved to protection storage, the TSDM sends an acknowledgment to the ESXi host that the operation is complete. The vCenter level task is marked as complete.
9. The last step is the metadata write to protection storage. In this step, the VM metadata (such as VMX Files, Manifest, and the last TSDM Snapshot information) is transferred using the VM Direct Engine VMware APIs.

**Note:** From this point in time, the files on the PowerProtect appliance are crash consistent and can be used for recovery. For a full backup, both full sync and delta sync are performed. However, for an incremental backup, only delta sync is performed. A full sync can back up four VM disks in parallel; a delta sync can back up 10 VM disks in parallel.

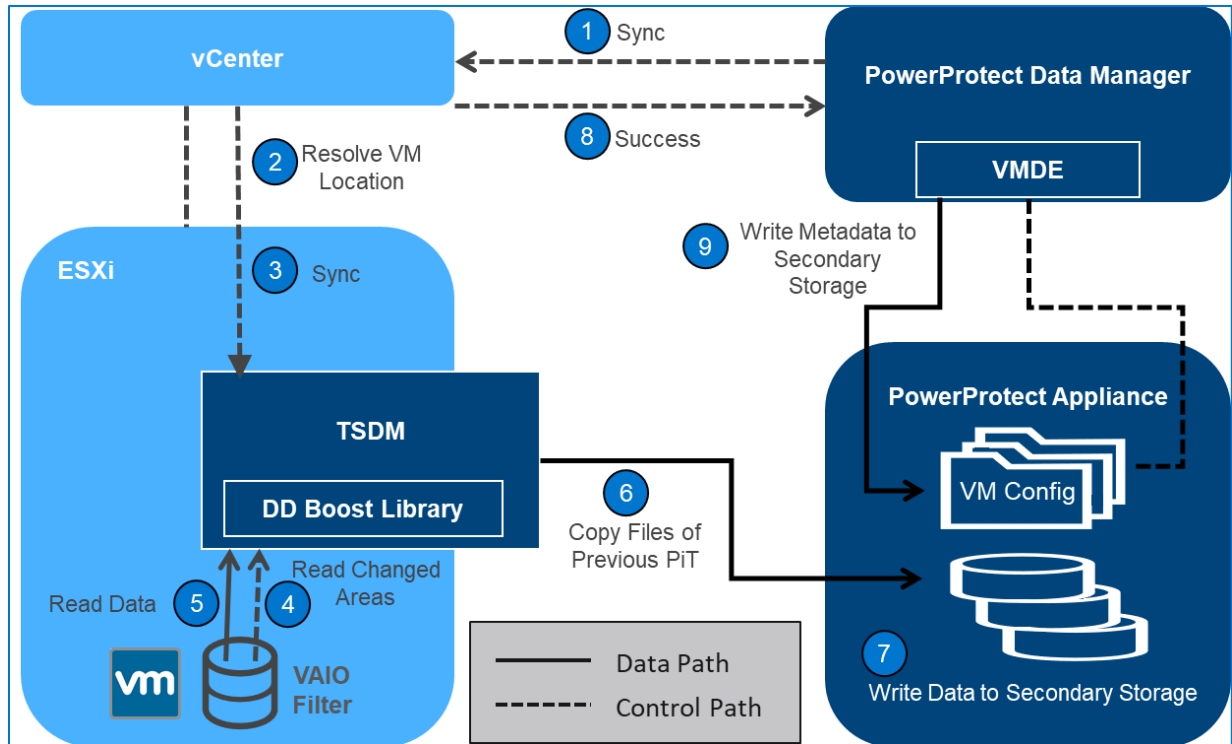


Figure 8 Delta sync operation

## 4.4 Snapshot retire operation

1. After the delta sync operation is complete, PowerProtect Data Manager ensures that the snapshot that was created before is deleted (see Figure 9). PowerProtect Data Manager now calls on vCenter to invoke the retire snapshot API towards the relevant ESXi host.
2. The ESXi host relays this information to all the relevant VAIO Filters to delete all the bitmaps and copy-on-write data residue left from the snapshot creation and delta sync stages.
3. The ESXi host sends an acknowledgment of the snapshot-retire success to vCenter and PowerProtect Data Manager.
4. PowerProtect Data Manager records the backup copy set information in the PowerProtect Data Manager Catalog and informs the search node (if any) to start gathering metadata for indexing.

Asset	Stat...	Er...	Size	Data ...	Redu...	Summary
Linux-02_NoStun	✔ Succ...	--	17.2 GB	3.8 GB	88.9 %	Description : Backup has SUCCEEDED. Total VMs backed up: 1 ProxyHostName : localhost TransportModeUsed : SDM ParallelismUsed : 1 BackupLevel : Full Overall : CompressedSize : 418.5 MB AverageThroughput : 39.5 MB/s

Note the following:

- Transparent snapshots are supported on VMFS, NFS, and vSAN Datastores. VMware vSphere Virtual Volumes (vVols) are not supported.
- Encrypted VMDKs are not supported with transparent snapshots.
- Virtual and physical RDM modes are not supported with transparent snapshots.

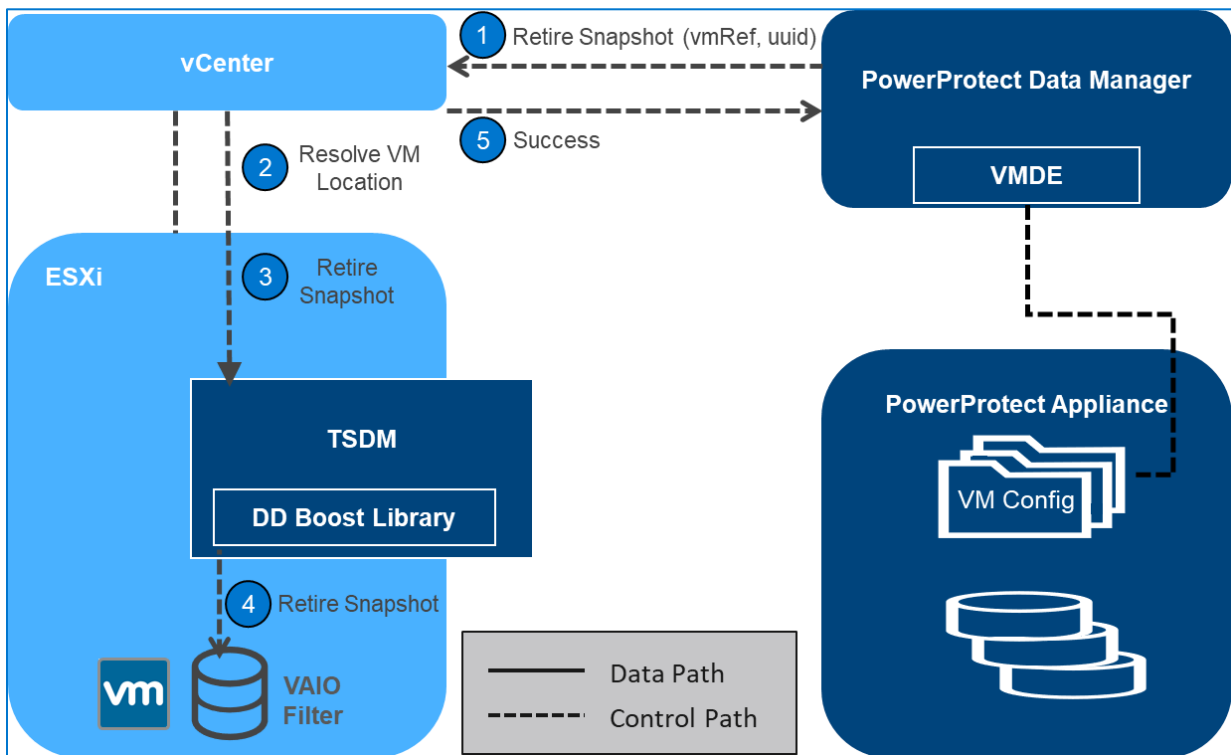


Figure 9 Snapshot retire operation



## 5 Restoring virtual machines

1. Before invoking any APIs from PowerProtect Data Manager to vCenter, PowerProtect Data Manager takes care of the configuration of the VM. For example, if a disk should be added or removed because the VM changed after the snapshot was taken, the disk might be added. For this reason, the reconfiguration part is performed beforehand.
2. A metadata only snapshot is taken using the same snapshot creation flow described in the section Transparent snapshots creation.
3. PowerProtect Data Manager invokes the restore operation, directing which VM should be restored to what point in time.
4. The VM is checked to determine if it is in a powered off state. If it is not, the VM is powered off.
5. PowerProtect Data Manager locates the relevant ESXi host through vCenter, and the ESXi host communicates with the TSDM to initiate a restore operation.
6. For a restore workflow, first, reserve all the areas of the disks of the VM that should be reverted to the previous point in time, for the following reasons:
  - Minimize the data you transfer from the protection storage back to the disk.
  - Identify which parts of each disk have changed since the point in time to which we are trying to revert.
7. To resolve the changes (described above), the restore workflow leverages two Get Diff APIs, namely Get VAIO Diff API and the DD Get Diff API.
8. The ESXi host resolves the Get VAIO Diff API. This difference includes the changes that the VM has made to the disks since the last point in time that was previously synced or backed up to the PowerProtect appliance. The VAIO Diff uses the metadata only snapshot, taken before the VM was powered off, to get the details on what was never written to the PowerProtect appliance.
9. The DD Get Diff API provides the delta details between the last sync point-in-time and the one to revert. It also merges the delta with the delta returned from the previous step. This step provides the complete set of extents that can now be read from the PowerProtect appliance.
10. From the point-in-time copy to which the user wants to revert, data is read and then finally written on top of the VMDKs.
11. After all the data movement is complete, the TSDM sends an acknowledgment to the ESXi host that the restore process has been completed.
12. vCenter marks the task completed and sends an acknowledgment to PowerProtect Data Manager for catalog update.
13. The VM can now be powered on and should have been successfully reverted to the previous point in time.
14. The metadata only snapshot can now be retired, in the same manner as after every delta sync operation.

Note the following:

- Multiple streams are opened on the TSDM (when ESXi receives the request) to achieve restore parallelism. You can achieve a higher level of parallelism if the VMs are spread across multiple ESXi hosts.
- Restore in parallel supports up to eight disks of a VM using transparent snapshots.
- Only Restore to Original and New are supported with PowerProtect Data Manager 19.9 release using transparent snapshots. Although instant access and File Level Restore are not supported at this time with transparent snapshots, they would default to a restore workflow using VM Proxies (vProxy) if performed.

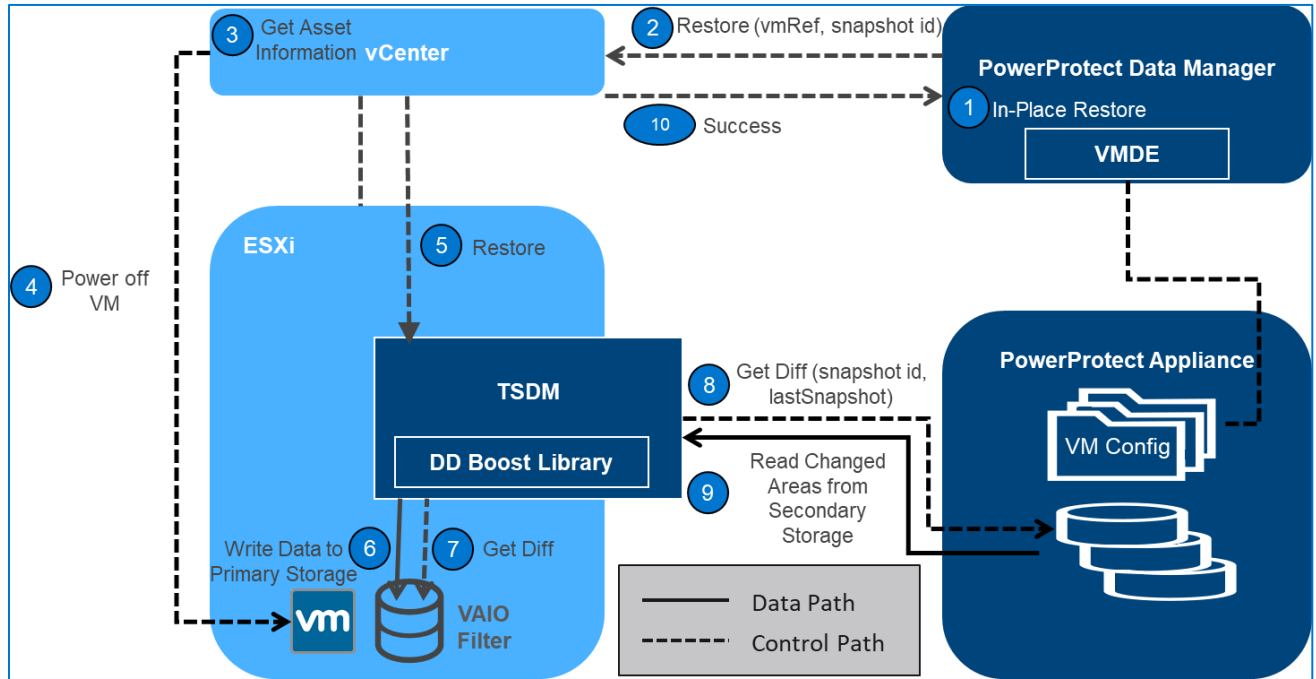


Figure 10 Restoring virtual machines

## 6 Performance test results

This section compares the I/O characterization between VMware API for Data Protection (VADP) and transparent snapshots using PowerProtect Data Manager 19.9. You can infer from these results that with transparent snapshots, you overcome the penalties of the write and the read latencies. This result can reduce VM latency by up to five times and provide up to five times faster backups.

**Disclaimer:** These results compare PowerProtect Data Manager 19.9 with transparent snapshots backup performance (performance-optimized mode) to PowerProtect Data Manager with VADP backup performance. The results are based on Dell Technologies internal testing in August 2021.

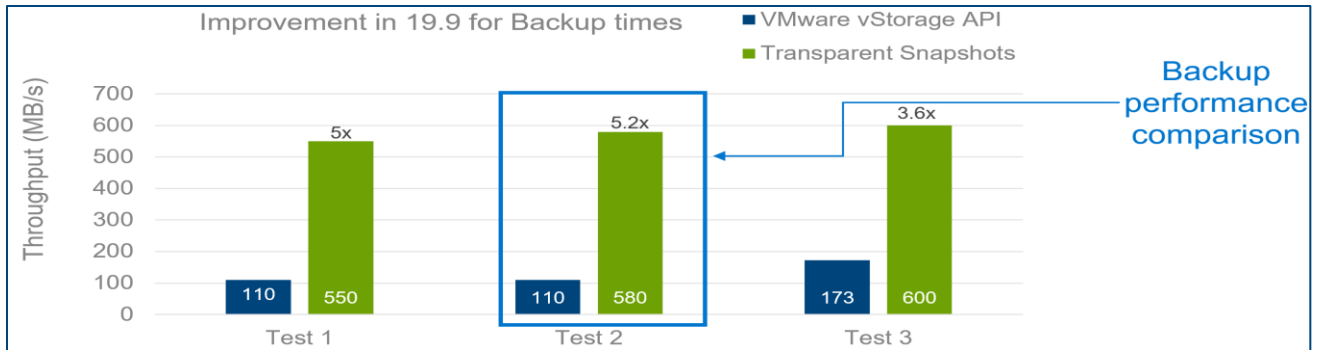


Figure 11 Backup performance comparison

	Transparent Snapshot	VADP
Test 1	<b>Effective IOPS during Sync: AVR - 10K</b> <b>Sync transfer rate: AVR - 550 MB/s</b> <b>Latency:</b> During Sync: AVR - 1 ms No Sync: AVR - 0.5 ms	<b>Effective IOPS during Sync: AVR - 10K</b> <b>Sync transfer rate: AVR - 110 MB/s</b> <b>Latency:</b> During Sync: AVR - Read: 1 ms / Write: 2.2 ms No Sync: AVR - 0.5 ms
Test 2	<b>Effective IOPS during Sync: AVR - 10K</b> <b>Sync transfer rate: AVR - 580 MB/s</b> <b>Latency:</b> During Sync: AVR - 1 ms No Sync: AVR - 0.5 ms	<b>Effective IOPS during Sync: AVR - 10K</b> <b>Sync transfer rate: AVR - 110 MB/s</b> <b>Latency:</b> During Sync: AVR - Read: 1 ms / Write: 2 ms No Sync: AVR - 0.5 ms
Test 3	<b>Effective IOPS during Sync: AVR - 10K</b> <b>Sync transfer rate: AVR - 610 MB/s</b> <b>Latency:</b> During Sync: AVR - 1 ms No Sync: AVR - 0.5 ms	<b>Effective IOPS during Sync: AVR - 10K</b> <b>Sync transfer rate: AVR - 173 MB/s with 12 DD Streams</b> <b>Latency:</b> During Sync: AVR - Read: 1.1 ms / Write: 2.5 ms No Sync: AVR - 0.5 ms

Figure 12 Backup performance comparison test details

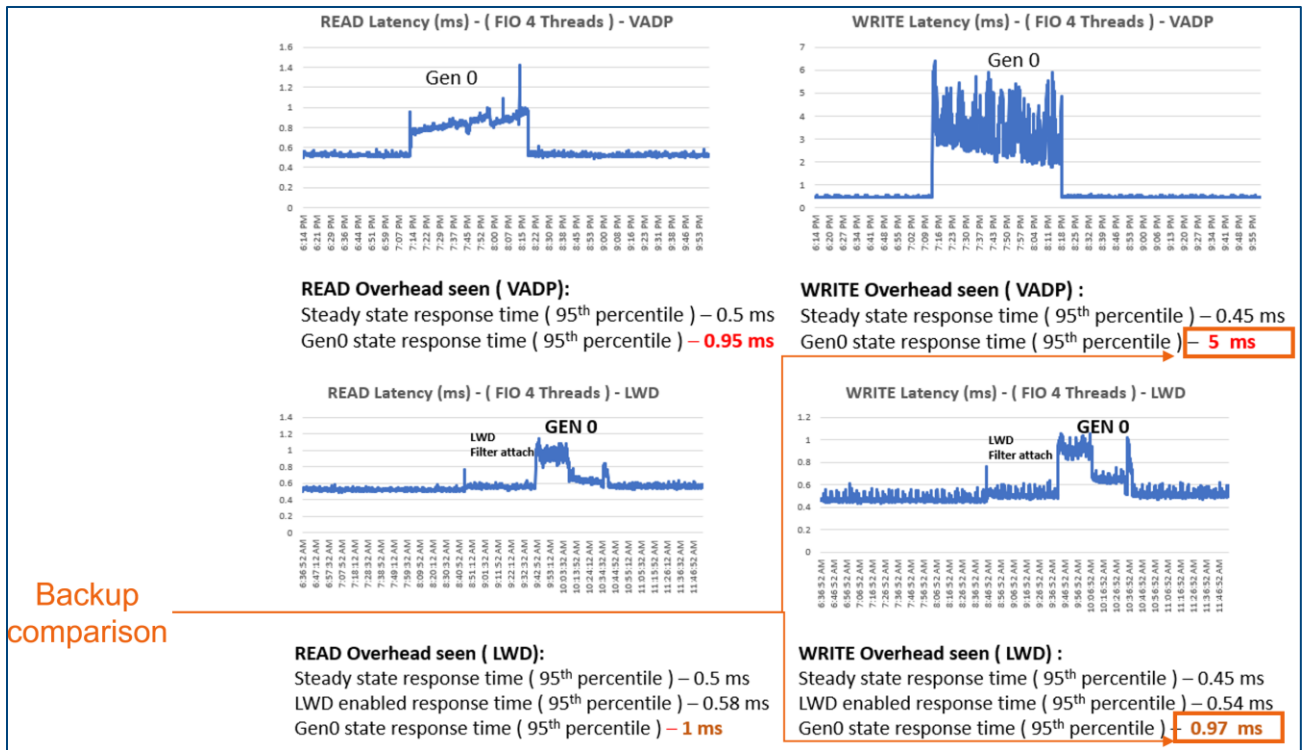


Figure 13 VM latency (read and write) performance comparison

## 6.1 Performance improvements in PowerProtect Data Manager 19.10

### 6.1.1 Restore performance

The following results show the restore performance improvement of PowerProtect Data Manager 19.10 compared to PowerProtect Data Manager 19.9.

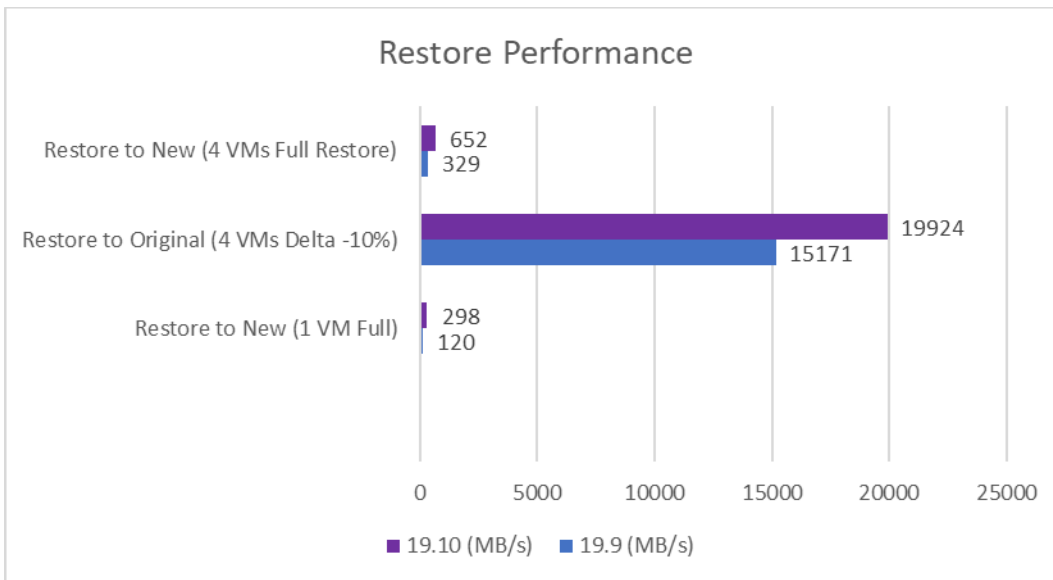


Figure 14 Restore performance comparison

Test	19.9 Throughput (MB/s)	19.10 Throughput (MB/s)	% Improvement
Restore to New (1 VM Full)	120	298	148.3
Restore to Original (4 VMs Delta -10%)	15171	19924	31.3
Restore to New (4 VMs Full Restore)	329	652	98.2

Figure 15 Restore performance comparison test details

## A Technical support and resources

The [Dell Technologies Info Hub](#) provides expertise to ensure customer success with Dell data protection products.

[Dell.com/support](#) is focused on meeting customer needs with proven services and support.

### A.1 Related resources

Other resources:

- [PowerProtect Data Manager Interactive Demo](#)
- [PowerProtect Official Documentation](#)
- [VMware vSphere APIs for I/O Filtering \(VAIO\)](#)