Technical Report

SAP HANA on VMware vSphere with NetApp FAS and All Flash FAS Systems
Reference Architecture

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Abstract

This reference architecture document helps customers design and deploy SAP HANA single host and multiple host solutions on VMware vSphere virtual machines (VMs) and NetApp® FAS and All Flash FAS (AFF) storage systems. This reference architecture is a deployed and documented solution based on experiences with existing VMware and NetApp customers, real-world simulations, and NetApp Engineering Lab validations. This document helps customers through the entire project lifecycle, including requirement assessment, solution design, installation, and administration.
1 Introduction

1.1 Introduction to SAP HANA

SAP HANA, which was developed to address the need of SAP customers for high-speed analytics, has evolved into a high-speed database for almost all SAP applications. It is the core of SAP’s digital transformation strategy. SAP HANA is an in-memory database that allows a computer’s main memory to process a vast quantity of transactional and analytical data.

You can use SAP HANA to develop business applications that support real-time analytics. These applications are flexible and capable of the performance needed to rapidly adapt to and act upon change. Even though SAP HANA is an in-memory database, it uses disk-based storage to persist changes. If there is a system failure or a system shutdown, the NetApp storage system acts as the persistence layer.

The SAP certification program for technology vendors validates functionality by hardware product. SAP requires that all appliances compatible with SAP HANA be tested and certified before they are used by customers. Although this certification is performed directly by SAP, server companies are responsible for building, delivering, and supporting their appliances.

SAP has also created a tailored data center integration (TDI) program that allows customers to build custom SAP HANA environments outside of the appliance model. This allows customers to use servers, networks, and storage from certified vendors to build custom SAP HANA environments. To receive SAP support, customers and partners must configure components and perform tests with tools provided by SAP to validate that a custom configuration meets SAP HANA performance requirements. More details about SAP HANA and TDI can be found in the SAP HANA tailored data center integration FAQ.

This document focuses on SAP HANA single host and multiple host deployments as a part of the TDI program. This includes certified NetApp FAS and NetApp All Flash FAS (AFF) storage systems, certified VMware vSphere virtualization, and the cloud computing platform.

1.2 Introduction to NetApp Storage Systems for SAP HANA

The NetApp FAS and AFF product families have been certified for use with SAP HANA in TDI projects. This certified enterprise storage platform is characterized by the NetApp ONTAP® storage operating system.

This certification is valid for the following current NetApp models:

- FAS8020, FAS8040, FAS8060, FAS8080 EX
- AFF8040, AFF8060, AFF8080 EX
- FAS2650, FAS8200, FAS9000
- AFF A200, AFF A300, AFF A700s, AFF A700

The most current information about certified storage systems can be found on the official SAP HANA hardware directory.

In addition to the information provided in this document, details on SAP HANA deployments with NetApp storage systems can be found in the NetApp FAS and AFF configuration guides listed in the references section.

1.3 Introduction to VMware vSphere for SAP HANA

VMware vSphere is the market leading virtualization platform and an enabling technology for cloud computing architectures. vSphere enables IT to meet SLA for the most demanding business-critical applications at the lowest TCO. VMware vSphere delivers control over all IT resources with the highest efficiency and choice in the industry.

VMware vSphere virtualization solutions provide the following benefits:
• **Consolidation.** VMware virtualization consolidates multiple application servers onto one physical server, with little or no decrease in overall performance. This arrangement minimizes or eliminates underutilized server hardware, software, and infrastructure.

• **Manageability.** The live migration of VMs from server to server and associated storage is performed with no downtime using VMware vSphere vMotion. This capability simplifies common operations such as hardware maintenance and VMware vSphere Storage vMotion.

• **Availability.** High availability (HA) can reduce unplanned downtime and enable higher service levels for applications. In the event of an unplanned hardware failure, VMware vSphere HA automatically restarts the affected VMs on another host in a VMware cluster.

• **Automation.** VMware automated load balancing takes advantage of vMotion and Storage vMotion to migrate VMs among a set of VMware ESX hosts. VMware vSphere Distributed Resource Scheduler (DRS) and VMware vSphere Storage DRS enable automatic resource relocation and optimization decisions for VMs and storage.

• **Provisioning.** VMware virtualization encapsulates an application into an image that can be duplicated or moved, greatly reducing the cost of application provisioning and deployment.

• **Control.** Single pane of glass control, management, and operation of the complete virtualized infrastructure with the VMware vCenter Server.

Figure 1) VMware vSphere overview.
vSphere creates a layer of abstraction between the resources required by an application, the operating system, and the underlying hardware that provides those resources. vSphere enables multiple, isolated execution environments to share a single hardware platform and provides each environment with its own set of hardware resources.

For more information, see the references section at the end of this paper.

vSphere 5.5 Compared to 6.x

The vSphere 6.x enhancement most relevant to VM implementation is an increase in scalability that allows SAP HANA VMs of up to 4TiB in size with vSphere 6.0. In addition, VMs can be up to 6TiB in size once certified with vSphere 6.5.

Although vSphere 6.x provides many improvements, including increased scalability, over vSphere 5.x, a vSphere 5.5-based SAP HANA VM can be migrated to 6.x without difficulty. During migration, the VM configuration settings must be updated and where needed, changed to run optimally on vSphere 6.x. See the VMware SAP HANA best practices document for more information about the support status and different settings.

VMware internal performance tests have shown that an identically configured SAP HANA vSphere 6.x VM running on the same server system has similar performance to a vSphere 5.5 VM. These tests have shown few performance benefits for vSphere 6.x in the area of memory management. However, vSphere 6.x VMs have access to more compute resources and provide more resources to an application. The application can then consume twice as many CPU threads (128) relative to vSphere 5.5 (64).

1.4 Customer Requirements

When the SAP HANA platform is powered using the VMware vSphere virtualization and cloud-computing platform, it delivers a new deployment architecture to VMware HANA customers. The SAP HANA with VMware solution provides SAP customers with a data center platform characterized by agility, high availability, cost savings, and easy provisioning. With this solution, SAP customers can provision instances of SAP HANA in VMs more quickly and cost effectively.

This joint VMware and NetApp reference architecture addresses the following requirements of customers running SAP HANA landscapes:

- **Lower TCO**
  - Reduced capital and operating expenditures
  - Unified management of SAP HANA with the rest of the virtualized data center (no specialized staff required)
  - Better utilization of existing infrastructure

- **Faster time to value**
  - Rapid, automated provisioning
  - Deployment time reduced from days to hours
  - Consistency across environments with template provisioning
  - Storage cloning for development and test systems

- **Higher service levels**
  - Live migration of SAP HANA VMs across hosts with zero planned downtime by using vSphere vMotion
  - Out-of-the-box high availability up to 99.9%:
    - Automatic restarts of SAP HANA VMs to maximize uptime
    - Automatic failover to virtual SAP HANA appliances with no data loss
  - Easy management of peak analytic workloads
Nondisruptive storage operations

- Efficient NetApp Snapshot® technology-based backups:
  - Minimized performance effects on production systems:
    - Dramatic reductions in the time required for backup, and restore, and recovery
    - A reduction in the amount of disk space needed for backups
  - Storage replication for disaster recovery scenarios

2 Reference Architecture Design and Deployment

2.1 Hardware

The infrastructure described in this document is designed to provide a homogeneous landscape and operational model for both SAP HANA systems and SAP systems running on traditional databases. To achieve this goal, you can use NetApp systems running ONTAP on the storage layer and VMware vSphere Enterprise Plus Edition as a hypervisor on top of the compute layer (Figure 2). Production SAP HANA systems have specific performance requirements, and SAP has defined strict rules and key performance indicators. Therefore, NetApp highly recommends dedicating parts of the physical infrastructure exclusively to SAP HANA workloads. Therefore, this document only focuses on SAP HANA systems. However, the management and operational concepts presented in this document span the complete environment and include systems other than SAP HANA.

Figure 2) Hardware landscape overview.

Storage Design and Configuration

This solution uses NetApp SAP HANA TDI-certified FAS or AFF systems running ONTAP on primary and secondary sites to provide storage-based replication for disaster recovery. Depending on customer SLAs, other disaster recovery options like SAP HANA system replication can be used. Replication is performed using NetApp SnapMirror® relationships between the two sites. The backup architecture uses the built-in ONTAP mechanism to back up SAP HANA databases. This storage-based Snapshot backup is a fully supported and integrated backup solution available since SAP HANA SPS7.
In addition, NetApp SnapVault® software is used to replicate Snapshot-based backups to a separate physical storage system to allow longer-term backup retention. An overview of the storage design is shown in Figure 3. Storage is sized according to the performance and capacity requirements of the production SAP HANA systems in a TDI deployment model. Details about correct sizing and configuration can be found in the SAP HANA on NetApp Systems with NFS Configuration Guide or the respective document for AFF.

NetApp recommends storing data for SAP HANA systems in NetApp FlexVol® volumes connected through the NFS protocol. You should also mount these volumes directly into the guest operating systems because doing so offers greater flexibility and simplified management in heterogeneous landscapes. This guide focuses on such an NFS-based setup. However, NetApp also supports the use of NetApp storage systems in a SAN environment connecting FCP LUNs as raw device maps (RDMs) to the SAP HANA VMs. Details and best practices for the storage setup in SAN environments can be found in the SAP HANA on NetApp FAS Systems with FC Configuration Guide or the respective document for AFF.

You can also store SAP HANA data in VMware virtual machine disks (VMDKs) provided through NFS or VMFS datastores. A storage design and sizing approach similar to the NFS or FCP setup should be considered when planning to use VMDKs. VMware highly recommends creating individual datastores for SAP HANA data and log VMDKs. The VMware best practices guides for SAP HANA provide more details for this scenario.

Figure 3) Storage overview.

Network Design and Configuration

Because all data for SAP HANA instances, including performance-critical data and log volumes for the database, is provided through NFS in this solution, proper network design and configuration are crucial. A dedicated storage network is used to separate the NFS traffic from communication and user access traffic between SAP HANA nodes. Each SAP HANA node requires a redundant dedicated network connection with a minimum of 10Gb of bandwidth. 40GbE is also supported. This network must extend end to end from the storage layer through network switching and computing up to the guest operating system hosted on VMware vSphere. In addition to the physical switching infrastructure, a VMware distributed switch (vDS) is used to provide adequate performance and manageability of network traffic at the hypervisor layer.
As is shown in Figure 4, each SAP HANA node uses a dedicated port group on the VMware distributed switch. This port group allows for enhanced quality of service (QoS) and dedicated assignment of physical network interface cards (NICs) on the ESX hosts. To use dedicated physical NICs while preserving HA capabilities if there was a NIC failure, the dedicated physical NIC is configured as an active uplink. Additional NICs are configured as standby uplinks in the teaming and failover settings of the SAP HANA port group. In addition, jumbo frames (MTU 9,000) must be enabled end to end on physical and virtual switches. In addition, turn off flow control on all 10GbE ports on servers, switches, and storage systems. Figure 5 shows an example of such a configuration.

**Note:** In contrast to previous versions of this document, the latency sensitivity settings for VMs should be left set to normal (default value).

For some NFS version and OS combinations, LRO (large receive offload) might need to be turned off.

For all other network configuration guidelines, see the respective VMware best practices guides for SAP HANA.
Computing Design and Configuration

Only SAP HANA certified and supported server systems can be used for SAP HANA production systems. If VMware virtualization is used, these systems should also be VMware certified. Verify the SAP and VMware support status before implementation.

At the time of writing, SAP provides full production support for SAP HANA on VMware vSphere 5.5 with all SAP deployment options. vSphere 6.0 and 6.5 is fully supported for SAP HANA single host deployments. SAP HANA multiple host support with vSphere 6.x was not available at the time of writing. For an up-to-date support statement for SAP HANA on VMware vSphere, see the SAP HANA on VMware Wiki Pages and the listed SAP support notes.

Advanced vSphere Datacenter features such as VMware vMotion, DRS, or VMware HA are supported by SAP and VMware. These features can be used with single or multiple SAP HANA instances on the virtualized infrastructure.

When sizing the compute environment, you must provide target SAP HANA instances available on the ESX hosts with sufficient main memory. Due to the in-memory architecture of SAP HANA, memory overcommitment is not supported. You can use SAP HANA VM system memory sizes of up to 1TB with vSphere 5.5 and up to 4TB with vSphere 6.x. Once validated, vRAM sizes up to 6TB are supported with vSphere 6.5.

You must provide proper bandwidth for high-performance storage access through NFS for the SAP HANA instances. Therefore, at least one dedicated physical NIC per SAP HANA node serving as uplink to the VMware distributed switch must be available on each server. For more information, see the section “Network Design and Configuration.”

You should set up and configure SAP HANA VMs according to the VMware best practices guide for SAP HANA single host and multiple host deployments on the SAP and VMware Virtualization page.
2.2 Software

SAP HANA Deployment and Configuration

The installation of a new SAP HANA database on a VMware VM with NetApp storage can be subdivided into the following tasks:

- **VM deployment.** One or more new VMs must be deployed for the SAP HANA database according to the configuration rules and requirements described in the VMware SAP HANA best practices guides. The VMs can be deployed by using a predefined template or by performing a fresh installation of an operating system that supports SAP HANA. Examples include SUSE Linux Enterprise Server 11 Service Pack 3 (or later) and Red Hat Enterprise Linux for SAP HANA 6.5. As an addition to the configuration guidelines from the best practices guides, a dedicated virtual NIC using the VMXNET3 driver for SAP HANA storage access must be added to each VM.

- **Storage deployment.** Figure 6 shows the volume configuration for four single-node SAP HANA systems. The data and log volume of each SAP HANA system is distributed to different storage controllers. For example, volume SID1_data is configured on controller A, and volume SID1_log is configured on controller B. For each SAP HANA node, a data volume; a log volume; and a volume for executables, configuration, and application logs are configured.

Figure 6) Volume layout for SAP HANA systems.

The volumes for a single SAP HANA system are directly mounted to the provisioned guest operating system using the dedicated network connection to the storage. Storage and volume configuration details can be found in the respective NetApp configuration guides.

- **SAP HANA installation.** After the VM, OS, and storage preparation steps are completed, a standard SAP HANA installation is performed according to the SAP HANA installation and administration guide. If you manage the SAP HANA database or application servers with SAP Landscape Management (LaMa), including the relocation functionality, you should configure a virtual host name for the database prior to the installation. When you deploy a VMware virtualized SAP HANA multiple host system, a stand-by host is not required to protect the system. The steps for multiple host system installation without a stand-by host are described in the VMware SAP HANA best practices guide.
Application and Data Management Design

NetApp SnapCenter for SAP HANA

NetApp ONTAP software provides a built-in mechanism to back up SAP HANA databases. Storage-based Snapshot backups are a fully supported and integrated backup solution available for SAP HANA SPS7 and higher.

Storage-based Snapshot backups are implemented by using the NetApp SnapCenter® plug-in for SAP HANA, which allows consistent storage-based Snapshot backups by using the interfaces provided by the SAP HANA database. SnapCenter registers the Snapshot backups in the SAP HANA backup catalog so that the backups are visible within the SAP HANA studio. They can then be selected for restore and recovery operations.

By using SnapVault software, the Snapshot copies that were created on the primary storage can be replicated to the secondary backup storage controlled by SnapCenter. Different backup retention policies can be defined for backups on the primary storage and backups on the secondary storage. The SnapCenter plug-in for SAP HANA manages the retention of Snapshot copy-based data backups and log backups, including the housekeeping of the backup catalog. SnapCenter plug-in for SAP HANA also allows you to perform a block-integrity check of the SAP HANA database by running a file-based backup.

The database logs can be backed up directly to the secondary storage by using an NFS mount, as shown in Figure 7.

Figure 7) Backup architecture.

Storage-based Snapshot backups provide significant advantages compared to file-based backups. The advantages include the following:

- Fast backup (less than a minute)
- Fast restore on the storage layer (less than a minute)
- No performance impact on the SAP HANA database host, network, or storage during backup
- Space-efficient and bandwidth-efficient replication to secondary storage based on block changes

To install the SnapCenter software and the SAP HANA plug-in, complete the following high-level steps:
1. Install the SAP HANA hdbsql client software on a management server (communication host). The management server can be a small additional VM deployed in the VMware vSphere environment; it can be the host where SnapCenter is installed, or the SAP HANA host itself. More details about the different deployment options can be found in the TR-4614: SAP HANA Backup and Recovery with SnapCenter.

2. Install the SnapCenter software as described in the SnapCenter Software 3.0 Installation and Setup Guide. SnapCenter requires management access to the FAS or AFF systems.

To perform the configuration, complete the following steps:

1. Create a backup user in SAP HANA and create the SAP HANA user store configuration.
2. Prepare SnapVault replication on all storage controllers.
3. Create volumes on the secondary storage controller.
4. Initialize the SnapVault relationships for database volumes.
5. Configure the SnapCenter framework and the SAP HANA plug-in.

A detailed description of the installation and configuration steps is provided in the TR-4614: SAP HANA Backup and Recovery with SnapCenter.

SAP Landscape Management Configuration

The enterprise edition of the SAP LaMa software helps users reduce the TCO of their SAP systems and improve their business agility. This software simplifies and automates the configuration, provisioning, deployment, monitoring, and management of their systems in both physical and virtualized infrastructures.

SAP LaMa provides a central point of control for assigning computing hosts and managing instances in the system landscape. SAP LaMa is built on the following four key principles:

- **Unification.** Reduce the time and effort to transition to virtual and cloud environments by decoupling the application from the underlying infrastructure. Transitions are also facilitated by a unified view and management of the hardware, software, and virtualization layers and automated system relocation.
- **Completion.** Improve the ability to respond to business needs with support for the configuration, deployment, monitoring, and management of your SAP systems and landscapes in both physical and virtualized infrastructures. This support provides you with more infrastructure options and faster time to value.
- **Simplification.** Simplify management of SAP landscapes by providing end-to-end visibility of your systems, automating capacity management and other key functions, and hiding the technical complexities of physical and virtualized infrastructures from day-to-day operations.
- **Automation.** Reduce the capital investment in and operational costs of your SAP systems with capabilities that simplify and automate system copy, system clone, and system refresh operations. You can also schedule system operations in advance with a built-in task planner and the leverage virtualization to reduce hardware requirements and improve host utilization.

SAP LaMa is an optional component of this reference architecture. However, it can significantly improve the manageability of SAP and SAP HANA landscapes, particularly when relocating SAP HANA systems between virtual and physical servers. It is also useful when dealing with SAP HANA system replication scenarios.

SAP LaMa is installed as an additional management system in the landscape. The installation of SAP LaMa and the configuration of managed SAP landscapes are described in the document SAP Landscape Management 3.0, Enterprise Edition.
3 Use Cases

This section describes various important use cases for managing and operating SAP HANA environments. We focus on some specific options and benefits that are available when running SAP HANA on VMware vSphere and NetApp systems.

3.1 SAP HANA Backup and Recovery

Backup and Recovery with NFS, NFS Datastores, or Raw Device Mapping

This section provides an overview of backup and restore operations with SAP HANA stored in the following ways:

- On NFS volumes mounted directly to the guest OS
- On NFS datastores
- On RDM disks mapped to the VM in an FCP environment

Backup

You can create SAP HANA Snapshot copy-based database backups by using the SnapCenter GUI, the command line, the built-in SnapCenter scheduler, or an external scheduler such as the SAP LaMa task scheduler.

When SnapCenter is backing up the database, it performs the following steps:

1. It triggers an SAP HANA synchronized backup save point to create a consistent database image on the persistence layer.
2. It creates storage Snapshot copies for all data volumes of the database.
3. It registers the storage Snapshot backup within the SAP HANA backup catalog.
4. It deletes the SAP HANA backup save point.
5. It starts a SnapVault update for all data volumes (if configured and enabled).
6. It deletes storage Snapshot copies and deletes backups in the SAP HANA backup catalog based on the defined retention policy for backups at the primary storage. Snapshot copies on the secondary system are deleted based on the retention policy defined in ONTAP.
7. It deletes all log backups that are older than the oldest data backup on the file system and within the SAP HANA backup catalog. This step is only executed if log backup cleanup is enabled. The following screenshot depicts the SAP HANA backup catalog.
This process is valid for NAS environments with NFS, and SAN environments using FCP and RDM.

In a setup where SAP HANA data is stored in VMDKs on NFS datastores, the NetApp volumes used for the respective VMware datastores must be added to the HANA backup configuration in SnapCenter.

**Note:** Snapshot-based backups are always performed on the NetApp FlexVol volume level for each SAP HANA system individually. If VMDKs of multiple different SAP HANA systems are stored within the same datastore, Snapshot copies for these different SAP HANA systems are created in the same volume. This might lead to a situation where the maximum number of possible Snapshot copies per volume is reached and no further backups are possible. Therefore, datastore layout and SAP HANA VMDK placement must be carefully planned ahead to avoid this situation. Follow the VMware best practices for datastore layout.

**Restore and Recovery**

Restore and recovery of an SAP HANA database are performed using SAP HANA Studio and the SnapCenter as follows:

1. Start the recovery process in SAP HANA Studio. Provide a valid log backup location and select a valid data backup from the catalog. The external backup ID reflects the Snapshot name on the storage level. The Snapshot name is needed later on for the restore process.

2. Within SnapCenter, restore the data volume of the SAP HANA system. The volume can be restored either from the primary storage or from any existing SnapVault target location. As an alternative to a volume restore, single-file restore is possible as well.

3. After the data is restored, the backup catalog view in SAP HANA studio must be refreshed. It then shows that the restored backup is available for recovery. SAP HANA studio then performs the remaining steps of the recovery process automatically.

In a setup where SAP HANA data is stored in VMDKs, the restore type (for example, volume or single-file restore) is dependent on the datastore layout. Typically, single-file restore is the most appropriate way to restore the VMDK where the SAP HANA datafiles are stored. The following screenshot depicts single-file restore for SAP HANA stored in VMDKs.

More details about the backup and recovery procedures, including a detailed description about backup replication, can be found in TR-4614: SAP HANA Backup and Recovery with SnapCenter.

**Backup and Recovery with FCP and VMFS Datastores**

In an FCP environment where the SAP HANA data and log files are stored on VMDKs in VMFS datastores, the backup and recovery workflows are slightly different compared to the description above. This section describes more details of this scenario.
SAP HANA Database

We used an empty SAP HANA single-node database for all tests. The installed version of the SAP HANA 1.0 database is SPS12 running on the SuSE SLES 11 SP3 operating system. The following screenshot depicts an SAP HANA H01 test database.

VMware Datastores for SAP HANA

The SAP HANA database installation requires three separate areas on the file system to store persistent data:

- **SAP HANA data.** For database data files.
- **SAP HANA log.** For database online redo log files.
- **SAP HANA shared.** For binaries, trace files, configuration files, and so on.

According to the following VMware best practices:

- **Architecture Guidelines and Best Practices for Deployments of SAP HANA on VMware vSphere**, p. 55
- **Best Practices and Recommendations for Scale-Out Deployments of SAP HANA on VMware vSphere**, p. 72

VMware highly recommends that you create a storage layout with separate and isolated VMware datastores for SAP HANA data and log files.

According to the best practices for SAP HANA on NetApp with FC (TR-4436), create one LUN per volume. The VMDKs for the shared area can be stored on a shared datastore for multiple SAP HANA instances or on an NFS volume mounted to the OS directly.

The required datastores for the SAP HANA database can be provisioned using the NetApp Virtual Storage Console (VSC). The following screenshots show the creation of the datastore for the SAP HANA data volume. Because the used lab environment does not have an FC connection to the NetApp storage system on all ESX hosts, the datastore is directly provisioned on one of the connected hosts instead of the complete vSphere cluster.

1. Right-click the ESX cluster or (as shown in this case) dedicated ESX hosts and navigate to NetApp VSC. Select the Provision Datastore option.
2. Fill necessary information in the Provision Datastore wizard. The following screenshot depicts the datastore summary in this example.
The following screenshot depicts the NetApp LUN for the datastore.
VMware Virtual Machine for SAP HANA

To run the SAP HANA database, a separate VM is deployed. Separate VMDKs for SAP HANA data and log files are added to the VM and stored in the respective datastores.

The VMDKs for data and log show up as regular SCSI devices inside the VM guest OS. These devices have been formatted using the XFS file system and have been mounted to the appropriate location within the file system according to the SAP HANA requirements (described in TR-4436).
Backup of SAP HANA Database

The backup workflow is identical to the workflow described in TR-4614: SAP HANA Backup and Recovery with SnapCenter.

The following screenshots show a backup run in the lab environment.

The backup job is detailed in the SnapCenter job view.

The related storage Snapshot copy resulting from the SAP HANA backup is shown in NetApp System Manager.
After successful completion the new backup is visible in the SAP HANA backup catalog in SAP HANA studio.

**Restore and Recovery of SAP HANA Database**

The following sections describe how to restore and recover an SAP HANA database using either volume-based restore or single-file restore. Although volume-based restores offer an easy method of restoring Snapshot copy backups, additional actions are required for an active storage replication relationship (for example, SnapVault or SnapMirror). In this case, a single-file restore might be more appropriate. For more details, see TR-4614: SAP HANA Backup and Recovery with SnapCenter.

**Volume-Based Restore**

The following workflow describes the volume-based restore option.

1. Power off the SAP HANA virtual machine
2. Start the restore process in the SnapCenter GUI.
3. Provide the restore details. Select Complete Resource as the restore type to perform a volume-level restore. No other input is required.

4. Run the restore process and wait until it has successfully finished.
5. Power on the SAP HANA virtual machine.


7. Proceed through the wizard until the list of available backups is displayed. The restored backup is flagged as available.
8. Complete the SAP HANA recovery as usual.
Single-File Restore

The single-file restore workflow is nearly the same as the volume-based restore. The only difference is the actual restore operation option that is selected in SnapCenter.

1. Power off the SAP HANA virtual machine.
2. Start the restore process in the SnapCenter GUI.
3. Provide the restore details. Select File level as the restore type and select the LUN to restore.
4. Run the restore process and wait until it finishes successfully.
5. Run the remaining steps (5 through 8) described in the volume-based restore workflow.

### 3.2 SAP HANA High Availability

There are several options available to address high-availability requirements for SAP HANA. There are integral SAP HANA options like SAP HANA service auto-restart, SAP HANA host auto-failover for multiple host deployments, and SAP HANA system replication in combination. These features can be used with cluster management software like SuSE SLES HA. In an SAP HANA environment deployed on VMware vSphere, VMware HA functionality offers an easy and yet powerful alternative to address most customer SLAs for high availability.

The VMware HA feature for SAP HANA is applicable to both SAP HANA single-node and multiple host deployments. In addition, it doesn’t require stand-by VMs and specific SAP HANA HA and disaster recovery (DR) provider implementations, as is the case for the SAP HANA host auto-failover functionality. For more information about the different HA options in a VMware virtualized SAP HANA environment, read the [VMware best practices guide for SAP HANA](#).

### 3.3 SAP HANA Disaster Recovery

Different options are available to prepare SAP HANA environments for DR scenarios. SAP HANA itself provides DR capabilities on the application level using SAP HANA system replication. This process can be used for both synchronous and asynchronous replication of data to a disaster site. The other options are based on storage-based replication. For SAP HANA databases on NetApp systems, either asynchronous replication using SnapMirror software or synchronous replication using NetApp MetroCluster™ software can be used. Table 1 compares the recovery point objectives (RPOs) and recovery time objectives (RTOs) of the different DR solutions.

Table 1) Disaster recovery options for SAP HANA.

<table>
<thead>
<tr>
<th>RTO</th>
<th>SAP HANA System Replication with Dedicated DR Servers</th>
<th>SAP HANA System Replication with Shared DR Servers</th>
<th>NetApp SnapCenter and SnapMirror</th>
<th>NetApp MetroCluster</th>
</tr>
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<tbody>
<tr>
<td>RTO</td>
<td>Very low – hot standby</td>
<td>Medium – cold standby</td>
<td>Medium – cold standby</td>
<td>Medium – cold standby</td>
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</table>
Asynchronous replication is handled by the SAP HANA plug-in for SnapCenter. This plug-in also manages the Snapshot copy-based backup solution (see the previous section). In SAP HANA environments based on vSphere, the disaster recovery process can be further optimized and streamlined by using preconfigured VM templates for the DR site. In the case of a disaster, these VMs can be quickly deployed on demand or powered on if they already exist.

In response to a disaster, use the following procedure for a failover of SAP HANA systems using asynchronous storage replication and vSphere:

1. Deploy an SAP HANA disaster VM on the DR site from an existing template or power on an already deployed VM.
2. Break the SnapMirror relationship on the target storage system that was used to asynchronously replicate data to the DR site. Restore the DR volumes to an existing (usually the latest) storage Snapshot copy.
3. Stop any SAP HANA nonproduction system on the DR site if the hardware resources have been sized to run either nonproduction systems or DR systems exclusively.

Mount the DR volumes on the target VM and adjust the network settings if needed. If the SAP HANA system is set up according to the SAP adaptive computing principle, mounting the volumes and adjusting network settings can be performed using the prepare functionality of SAP LaMa (see also the use case Follow the best practices for SAP HANA vMotion as outlined in the VMware HANA best practices document starting on page 35.

4. SAP LaMa Relocation).
5. Start SAP HANA. If the configuration of the SAP HANA system on the DR site is not identical to the production site, some postprocessing steps must be performed before starting SAP HANA.

See TR-4646 SAP HANA Disaster Recovery with Asynchronous Storage Replication Using SnapCenter 3.0 for more details.
3.4 SAP HANA System Copy and Refresh

Typical SAP landscapes consist of one or more production SAP systems along with a number of development, test, training, project, and sandbox systems. These non-production systems are often created or refreshed based on data from the production system. This is also the case for system landscapes based on SAP HANA databases.

Homogeneous system copies can be created by recovering an existing data backup. Using NetApp Snapshot integration for backups along with NetApp FlexClone® technology and vSphere rapid VM deployment, this task can be performed within minutes instead of hours or even days. Snapshot integration can also save a significant amount of storage space because no data is copied initially. The overall procedure differs slightly depending on whether you are performing an initial system copy or you are refreshing an existing SAP HANA database.

For an initial system copy, you must first install the target system. You can then perform the database refresh using the following steps:

1. Shut down the target database and unmount the data volume from the server.
2. Use the SnapCenter software to create a clone of the source database either by using an existing backup or by creating a new backup on demand. The SnapCenter software creates the volume clones and assigns export policies.
3. Mount the cloned data volume on the target host using the existing original mount point of the target database.
4. The database must be recovered based on the cloned backup. There are two options for this process:
   - If the SAP HANA database should be rolled forward, a copy of the respective log files must be available at the target host. The log files should be available either as a physical copy of the files or by mounting the source log volume.
   - The database can also be recovered without any logs if only the data up to the point in time of the Snapshot backup is required. In this case, no additional logs must be copied.
5. To finalize the database refresh, the database must be recovered (see the section “SAP HANA Backup and Recovery”). Start the SAP HANA recovery process using SAP HANA Studio and the Snapshot backup information that was used to clone the volumes. If the database should be rolled forward, make sure to provide the log backup location of the source system, as is seen in the following screenshot, not the one from the target system.

6. After the database is completely recovered, the standard steps needed to complete a homogeneous system copy on the SAP system (for example, logical system name conversion (BDLS), adjusting remote function call connections (RFC), and so on) must be performed.
More details about the different options for SAP HANA system copy and refresh processes can be found in TR-4439: Optimizing SAP Lifecycle Management with NetApp Solutions for SAP HANA.

### 3.5 SAP HANA Relocation

#### VMware vMotion

VMware vMotion, a key feature of enterprise virtual infrastructure, enables live migration of a running VM from one physical host to another. Migration of a VM with vMotion preserves the precise execution state of a VM consisting of physical memory, storage, and the virtual device state (including CPU, network and disk adapters, and SVGA). The VM continues to run throughout the migration process with minimal impact on user workload and no disruption to network connectivity.

vMotion is a business continuity solution that brings invaluable benefits to administrators because it helps prevent application downtime, enables zero-downtime maintenance and troubleshooting and improves flexibility. vMotion is a key enabler of several VMware technologies, including vSphere DRS and vSphere distributed power management (DPM). These technologies together create a dynamic, automated, and self-optimizing data center.

Some of the features of vMotion include:

- Live migration of an entire VM across vSphere hosts without any requirement for shared storage
- A multi-NIC capability that transparently load-balances vMotion traffic over all of the NICs enabled by vMotion
- Concurrent vMotion migrations to reduce overall migration time in VM evacuation scenarios
- Live migration on metro networks with round-trip latencies of up to 10ms

Follow the best practices for SAP HANA vMotion as outlined in the VMware HANA best practices document starting on page 35.

#### SAP LaMa Relocation

SAP systems can be installed using the SAP adaptive computing approach to enable application virtualization for SAP systems by decoupling the application from the operating system. Installing SAP systems as adaptive-enabled systems is supported for all current systems based on NetWeaver, including SAP HANA. Such systems can be relocated from one operating system to another, including relocation from physical servers to VMs and back.

There are two important prerequisites for this functionality. First, all data that belongs to an SAP system must reside on an enterprise storage system, and, second, this data must be made available on all possible target hosts. These requirements are fulfilled with a certified NFS-based SAP HANA installation on NetApp storage.

Using application virtualization for an SAP HANA database adds a great deal of flexibility to the landscape. In particular, application virtualization overcomes temporary hardware constraints for large SAP HANA systems that might currently prevent customers from running those SAP HANA databases on VMs. For the time being, large SAP HANA database systems can be installed on physical servers. When support for larger VMs is available, SAP HANA databases can easily be relocated to the vSphere environment.

The process to relocate an SAP HANA database has the following main steps:

1. Stop the SAP HANA database.
2. Run the unprepare step of the SAP HANA database on the source host. In this step, the assigned virtual IP address is removed from the operating system, and the SAP HANA volumes are unmounted.
3. Prepare the SAP HANA database on the target host. A virtual IP address is added to the target host, and all necessary SAP HANA volumes are mounted.

4. Start the SAP HANA database on the target host. This can be another VM or a physical server.

These steps can be performed manually using SAP HANA studio to start and stop the database and operating system commands for IP address handling and storage volume mounting and unmounting. If SAP LAMA is installed in the environment, the built-in LAMA relocation functionality can be used as shown in Figure 8.

Figure 8) SAP HANA relocation using SAP LAMA.

The relocate functionality of SAP LAMA is part of the standard edition. Therefore, no additional license is needed for use.

4 Conclusion

SAP HANA customers require a high level of performance and data availability while preserving the flexibility, manageability, and operational benefits of modern virtualized data centers. They typically have large numbers of systems that are frequently created from copies of large production databases. These customers cannot afford extended periods of downtime or performance degradation because of backups or replication.

NetApp and VMware provide a complete end-to-end SAP HANA system environment and solution that allows customers to maintain a high level of data security while still meeting stringent performance and availability requirements.
Where to Find Additional Information

To learn more about the information described in this document, see the following documents and/or websites:

- TR-4435: SAP HANA on NetApp All Flash FAS Systems with NFS - Configuration Guide
- TR-4436: SAP HANA on NetApp All Flash FAS Systems with Fibre Channel Protocol - Configuration Guide
- TR-4279: SAP HANA Disaster Recovery with Asynchronous Storage Replication Using SnapCreator 3.0
- TR-4614: SAP HANA Backup and Recovery with SnapCenter
- TR-4439: Optimizing SAP Lifecycle Management with NetApp Solutions for SAP HANA
- VMware SAP HANA Best Practices, Recommendations for Scale-Up and –Out deployments and FAQ documents:
- VMware SAP HANA Best Practices and Architecture Guidelines:
- SAP HANA on VMware vSphere SCN Blog:
  https://wiki.scn.sap.com/wiki/display/VIRTUALIZATION/SAP%2BHANA+on+VMware+vSphere
- FAQ—SAP HANA tailored data center integration
  http://www.sap.com/documents/2016/05/e8705aae-717c-0010-82c7-eda71af511fa.html
- Overview—SAP HANA tailored data center integration
  http://www.sap.com/documents/2016/05/827c26ba-717c-0010-82c7-eda71af511fa.html
- White paper—SAP HANA Storage Requirements
  http://www.sap.com/documents/2015/03/74cdb554-5a7c-0010-82c7-eda71af511fa.html
- SAP certified enterprise storage for SAP HANA
- SAP Landscape Management 3.0, Enterprise Edition
  http://help.sap.com/nwlvx
- SAP HANA Administration Guide
- SAP Note 1844468—Homogenous system copy on SAP HANA
  http://service.sap.com/sap/support/notes/1844468

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