Abstract
The NetApp® FAS product family has been certified for use with SAP HANA in Tailored Data Center Integration (TDI) projects. This document describes best practices for a Fibre Channel (FC) storage setup using the NetApp ONTAP® operating system with the FAS product family.
TABLE OF CONTENTS

1 Introduction ......................................................................................................................................... 4
  1.1 SAP HANA Tailored Data Center Integration ................................................................................. 4

2 Architecture ....................................................................................................................................... 5
  2.1 SAP HANA Backup ....................................................................................................................... 6
  2.2 SAP HANA Disaster Recovery ..................................................................................................... 8

3 Storage Sizing .................................................................................................................................... 9
  3.1 Performance Considerations ....................................................................................................... 9
  3.2 Mixed Workloads ....................................................................................................................... 10
  3.3 Capacity Considerations .......................................................................................................... 10
  3.4 HWCCT Configuration for SAP HANA .................................................................................... 11
  3.5 Storage Sizing Process Overview ............................................................................................. 11

4 Infrastructure Setup and Configuration .......................................................................................... 12
  4.1 SAN Fabric Setup ..................................................................................................................... 12
  4.2 Time Synchronization ............................................................................................................... 12
  4.3 Storage Controller Setup ........................................................................................................ 12
  4.4 SAP HANA Storage Connector API ......................................................................................... 25
  4.5 Host Setup .................................................................................................................................. 26
  4.6 I/O Stack Configuration for SAP HANA ................................................................................... 30
  4.7 SAP HANA Software Installation ............................................................................................ 30

Where to Find Additional Information ................................................................................................. 32
Version History ..................................................................................................................................... 33

LIST OF TABLES
Table 1) Number of SAP HANA hosts per disk shelf ........................................................................ 10
Table 2) HWCCT configuration file parameter values ..................................................................... 11
Table 3) Volume configuration for SAP HANA single-host systems ............................................... 19
Table 4) Mount points for single-host systems ................................................................................ 19
Table 5) Volume configuration for SAP HANA multiple-host systems .......................................... 20
Table 6) Mount points for multiple-host systems .......................................................................... 20
Table 7) Volume options .................................................................................................................. 21

LIST OF FIGURES
Figure 1) SAP HANA TDI .................................................................................................................. 4
Figure 2) Example configuration with eight SAP HANA hosts. ................................................................. 5
Figure 3) Scaling by adding more disk capacity. ......................................................................................... 6
Figure 4) Scaling with additional storage systems .................................................................................... 6
Figure 5) Backup architecture. .................................................................................................................. 7
Figure 6) Asynchronous storage replication. ......................................................................................... 8
Figure 7) Synchronous storage replication. .............................................................................................. 9
Figure 8) Storage sizing overview. .......................................................................................................... 11
Figure 9) FCP SAN configuration example. .............................................................................................. 12
Figure 10) Disk shelf connection with HDDs. ......................................................................................... 14
Figure 11) Disk shelf connection with SSDs. ............................................................................................ 14
Figure 12) Aggregate layout with HDDs .................................................................................................. 15
Figure 13) Aggregate layout with SSDs. .................................................................................................. 15
Figure 14) Logical interface configuration. ............................................................................................... 16
Figure 15) FCP port set configuration. ...................................................................................................... 17
Figure 16) Initiator groups. ...................................................................................................................... 18
Figure 17) Volume layout for SAP HANA multiple-host and single-host systems. .................................. 18
Figure 18) Volume layout for SAP HANA multiple-host systems. ............................................................ 20
Figure 19) LUN summary. ....................................................................................................................... 25
1 Introduction

The NetApp FAS product family has been certified for use with SAP HANA in TDI projects. The certified enterprise storage platform is characterized by the NetApp ONTAP operating system.

The certification is valid for the following models:

- FAS8020, FAS8040, FAS8060, FAS8080 EX
- FAS2620, FAS2650, FAS2720, FAS2750, FAS8200, FAS9000

For a complete list of NetApp’s certified storage solutions for SAP HANA, see the certified and supported SAP HANA hardware directory.

This document describes FAS configurations that use the Fibre Channel Protocol (FCP). The configuration guides for FAS systems using NFS and NetApp AFF systems are at the following links:

- SAP HANA on NetApp AFF Systems with Fibre Channel Protocol
- SAP HANA on NetApp FAS Systems with NFS
- SAP HANA on NetApp AFF Systems with NFS

In an SAP HANA multiple-host environment, the standard SAP HANA storage connector is used to provide fencing in the event of an SAP HANA host failover. Refer to the relevant SAP notes for operating system configuration guidelines and HANA-specific Linux kernel dependencies. For more information, see SAP Note 2235581 – SAP HANA Supported Operating Systems.

1.1 SAP HANA Tailored Data Center Integration

NetApp FAS storage controllers are certified in the SAP HANA Tailored Data Center Integration (TDI) program using NFS (NAS) and Fibre Channel (SAN) protocols. They can be deployed in any SAP HANA scenario, such as, SAP Business Suite on HANA, S/4HANA, BW/4HANA or SAP Business Warehouse on HANA in single-host or multiple-host configurations. Any server that is certified for use with SAP HANA can be combined with the certified storage solution. See Figure 1 for an architecture overview.

![Figure 1) SAP HANA TDI.](image-url)
For more information regarding the prerequisites and recommendations for productive SAP HANA systems, see the following resources:

- SAP HANA Tailored Data Center Integration Frequently Asked Questions
- SAP HANA Storage Requirements

## 2 Architecture

SAP HANA hosts are connected to the storage controllers using a redundant FCP infrastructure and multipath software. A redundant FCP switch infrastructure is required to provide fault-tolerant SAP HANA host-to-storage connectivity in case of switch or host bus adapter (HBA) failure. Appropriate zoning must be configured at the switch to allow all HANA hosts to reach the required LUNs on the storage controllers.

Different models of the FAS product family can be used at the storage layer. The maximum number of SAP HANA hosts attached to the storage is defined by the SAP HANA performance requirements. The number of disk shelves required is determined by the capacity and performance requirements of the SAP HANA systems.

Figure 2 shows an example configuration with eight SAP HANA hosts attached to a storage HA pair.

Figure 2) Example configuration with eight SAP HANA hosts.

This architecture can be scaled in two dimensions:

- By attaching additional SAP HANA hosts and disk capacity to the storage, assuming that the storage controllers can provide enough performance under the new load to meet key performance indicators (KPIs)
- By adding more storage systems and disk capacity for the additional SAP HANA hosts

Figure 3 shows a configuration example in which more SAP HANA hosts are attached to the storage controllers. In this example, more disk shelves are necessary to meet the capacity and performance requirements of the 16 SAP HANA hosts. Depending on the total throughput requirements, you must add additional FC connections to the storage controllers.
Independent of the deployed FAS system storage model, the SAP HANA landscape can also be scaled by adding more storage controllers, as shown in Figure 4.

2.1 SAP HANA Backup

NetApp ONTAP software provides a built-in mechanism to back up SAP HANA databases. Storage-based Snapshot® backup is a fully supported and integrated backup solution available for SAP HANA single-container systems and for SAP HANA MDC single-tenant systems.

Storage-based Snapshot backups are implemented by using the NetApp SnapCenter® plug-in for SAP HANA, which enables 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 and can be selected for restore and recovery operations.

By using NetApp 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 for backups on the secondary storage. The SnapCenter Plug-in for SAP HANA Database manages the retention of Snapshot copy-based data backups and log backups including the housekeeping of the backup catalog. The SnapCenter Plug-in for SAP HANA Database also enables the execution of a block-integrity check of the SAP HANA database by performing 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 5.

Figure 5) Backup architecture.

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

- Faster backup (few minutes)
- Faster restore on the storage layer (a few minutes)
- No effect on the performance of the SAP HANA database host, network, or storage during backup
- Space-efficient and bandwidth-efficient replication to secondary storage based on block changes

For detailed information about the SAP HANA backup and recovery solution using SnapCenter, see TR-4614: SAP HANA Backup and Recovery with SnapCenter.
2.2 SAP HANA Disaster Recovery

SAP HANA disaster recovery can be performed on the database layer by using SAP system replication or on the storage layer by using storage-replication technologies. The following section provides an overview of disaster recovery solutions based on storage replication.

For detailed information about the SAP HANA disaster recovery solution using SnapCenter, see TR-4646: SAP HANA Disaster Recovery with Asynchronous Storage Replication.

The same SnapCenter Plug-in that is described in section 2.1, “SAP HANA Backup,” is also used for the asynchronous mirroring solution. A consistent Snapshot image of the database at the primary site is asynchronously replicated to the disaster recovery site by using NetApp SnapMirror® technology. The servers at the disaster recovery site can be used for development and testing during normal operation, as shown in Figure 6.

Space-efficient, instantaneous NetApp FlexClone® copies can be used at the disaster recovery site to run disaster failover tests without interrupting the replication process. FlexClone copies can also be used to create an SAP system copy and to refresh the test systems with current production data.

Figure 6) Asynchronous storage replication.

Synchronous Storage Replication

The synchronous disaster recovery solution for SAP HANA is based on NetApp MetroCluster™ high-availability and disaster recovery storage software. Figure 7 shows a high-level overview of the solution. The storage cluster at each site provides local high availability and is used for production workloads. The data at each site is synchronously replicated to the other location and is available in case of disaster failover.
3 Storage Sizing

The following section provides an overview of performance and capacity considerations for sizing a storage system for SAP HANA.

Note: Contact your NetApp or NetApp partner sales representative to support the storage sizing process and to create a properly sized storage environment.

3.1 Performance Considerations

SAP has defined a static set of storage KPIs. These KPIs are valid for all production SAP HANA environments independent of the memory size of the database hosts and the applications that use the SAP HANA database. These KPIs are valid for single-host, multiple-host, Business Suite on HANA, Business Warehouse on HANA, S/4HANA, and BW/4HANA environments. Therefore, the current performance sizing approach depends on only the number of active SAP HANA hosts that are attached to the storage system.

Note: Storage performance KPIs are required only for production SAP HANA systems.

SAP delivers a performance test tool, the Hardware Configuration Check Tool (HWCCT), which must be used to validate the storage performance for the number of active SAP HANA hosts attached to the storage.

The storage vendor defines the maximum number of SAP HANA hosts that can be attached to a specific storage model, while fulfilling the required storage performance KPIs from SAP for production SAP HANA systems.

Note: The storage controllers of the certified FAS product family can also be used for SAP HANA with other disk types or disk back-end solutions, as long as they are supported by NetApp and fulfill
This document describes disk sizing for SAS hard disk drives and solid-state drives.

**Hard Disk Drives**

A minimum of 10 data disks (10k RPM SAS) per SAP HANA node is required to fulfill the storage performance KPIs from SAP.

**Note:** This calculation is independent of the storage controller and disk shelf used.

**Solid-State Drives**

With solid-state drives (SSDs), the number of data disks is determined by the SAS connection throughput from the storage controllers to the SSD shelf.

The maximum number of SAP HANA hosts that can be run on a disk shelf and the minimum number of SSDs required per SAP HANA host were determined by running the SAP performance test tool.

- The 12Gb SAS disk shelf (DS224C) with 24 SSDs supports up to 14 SAP HANA hosts, when the disk shelf is connected with 12Gb.
- The 6Gb SAS disk shelf (DS2246) with 24 SSDs supports up to 4 SAP HANA hosts.

The SSDs and the SAP HANA hosts must be equally distributed between both storage controllers.

Table 1 summarizes the supported number of SAP HANA hosts per disk shelf.

<table>
<thead>
<tr>
<th>Maximum number of SAP HANA hosts per disk shelf</th>
<th>6Gb SAS Shelves (DS2246) Fully Loaded with 24 SSDs</th>
<th>12Gb SAS Shelves (DS224C) Fully Loaded with 24 SSDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** This calculation is independent of the storage controller used.

### 3.2 Mixed Workloads

SAP HANA and other application workloads running on the same storage controller or in the same storage aggregate are supported. However, it is a NetApp best practice to separate SAP HANA workloads from all other application workloads.

You might decide to deploy SAP HANA workloads and other application workloads on either the same storage controller or the same aggregate. If so, you must make sure that sufficient performance is available at all times for SAP HANA within the mixed workload environment. NetApp also recommends that you use Quality of Service (QoS) parameters to regulate the impact these other applications could have on SAP HANA applications.

The SAP HWCCT test tool must be used to check if additional SAP HANA hosts can be run on a storage controller that is already used for other workloads. However, SAP application servers can be safely placed on the same storage controller and aggregate as the SAP HANA databases.

### 3.3 Capacity Considerations

A detailed description of the capacity requirements for SAP HANA is in the [SAP HANA Storage Requirements](#) white paper.

**Note:** The capacity sizing of the overall SAP landscape with multiple SAP HANA systems must be determined by using SAP HANA storage sizing tools from NetApp. Contact NetApp or your
3.4 HWCCT Configuration for SAP HANA

Starting with SAP HANA 1.0 SPS10, SAP introduced parameters to adjust the I/O behavior and optimize the database for the file and storage system used. These parameters must also be set for the performance test tool from SAP (fsperf) when the storage performance is tested by using the SAP HWCCT tool.

Performance tests were conducted by NetApp to define the optimal values. Table 2 lists the parameters that must be set within the configuration file of SAP HWCCT.

Table 2) HWCCT configuration file parameter values.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>max_parallel_io_requests</td>
<td>128</td>
</tr>
<tr>
<td>async_read_submit</td>
<td>on</td>
</tr>
<tr>
<td>async_write_submit_active</td>
<td>on</td>
</tr>
<tr>
<td>async_write_submit_blocks</td>
<td>all</td>
</tr>
</tbody>
</table>

More information about the configuration of SAP HWVAL is in SAP note 1943937.

3.5 Storage Sizing Process Overview

The number of disks per HANA host and the SAP HANA host density for each storage model were determined with HWCCT.

The sizing process requires details such as the number of production and nonproduction SAP HANA hosts, the RAM size of each host, and the backup retention period of the storage-based Snapshot copies. The number of SAP HANA hosts determines the storage controller and the number of disks required.

The size of the RAM, the net data size on the disk of each SAP HANA host, and the Snapshot copy backup retention period are used as inputs during capacity sizing.

Figure 8 summarizes the sizing process.
4 Infrastructure Setup and Configuration

The following sections provide SAP HANA infrastructure setup and configuration guidelines. All the steps needed to set up SAP HANA are included. An SVM is created to host the data. The storage system used in this example setup is a FAS8200, and the corresponding SVM is called hana.

4.1 SAN Fabric Setup

Each SAP HANA server must have a redundant FCP SAN connection with a minimum of 8Gb bandwidth. For each SAP HANA host attached to a storage controller, at least 8Gb of bandwidth must be configured at the storage controller.

Figure 9 shows an example with four SAP HANA hosts attached to two storage controllers. Each SAP HANA host has two FCP ports connected to the redundant fabric. At the storage layer, four FCP ports are configured to provide the required throughput for each SAP HANA host.

![SAN Fabric Configuration Example](image)

In addition to the zoning on the switch layer, you must map each LUN on the storage system to the hosts that connect to this LUN. Keep the zoning on the switch simple; that is, define one zone set in which all host HBAs can see all controller HBAs.

4.2 Time Synchronization

You must synchronize the time between the storage controllers and the SAP HANA database hosts. The same time server must be set for all storage controllers and all SAP HANA hosts.

4.3 Storage Controller Setup

This section describes the configuration of the NetApp storage system. You must complete the primary installation and setup according to the corresponding ONTAP setup and configuration guides.

Storage Efficiency

Inline deduplication, cross-volume inline deduplication, inline compression, and inline compaction are supported with SAP HANA in an SSD configuration.
Enabling the storage efficiency features in an HDD configuration is not supported.

**NetApp Volume Encryption**
The use of NetApp Volume Encryption (NVE) is supported for SAP HANA.

**Quality of Service**
Quality of service (QoS) can be used to limit the storage throughput for specific SAP HANA systems. One use case would be to limit the throughput of development and test systems so that they cannot influence production systems in a mixed setup.

During the sizing process, the performance requirements of a nonproduction system must be determined. Development and test systems can be sized with lower performance values, typically in the range of 20% to 50% of a production system.

Starting with ONTAP 9, QoS is configured on the storage volume level and uses maximum values for throughput (MBps) and number of I/Os (IOPS). Large write I/O has the biggest performance effect on the storage system. Therefore, the QoS throughput limit should be set to a percentage of the corresponding write SAP HANA storage performance KPI values in the data and log volumes.

**Configure Storage**
The following overview summarizes the required storage configuration steps. Each step is covered in more detail in the subsequent sections. Before initiating these steps, complete the storage hardware setup, the ONTAP software installation, and the connection of the storage FCP ports to the SAN fabric.

1. Check the correct SAS stack configuration, as described in “Disk Shelf Connection.”
2. Create and configure the required aggregates, as described in “Aggregate Configuration.”
3. Create a storage virtual machine (SVM) as described in “Storage Virtual Machine Configuration.”
4. Create logical interfaces (LIFs) as described in “Logical Interface Configuration.”
5. Create FCP port sets as described in “FCP Portsets.”
6. Create initiator groups with worldwide names (WWNs) of HANA servers as described in “Initiator Groups.”
7. Create volumes and LUNs within the aggregates as described in “Volume and LUN Configuration for SAP HANA Single-Host Systems” and “Volume and LUN Configuration for SAP HANA Multiple-Host Systems.”

**Disk Shelf Connection**
With HDDs, a maximum of two DS2246 disk shelves or four DS224C disk shelves can be connected to one SAS stack to provide the required performance for the SAP HANA hosts, as shown in Figure 10. The disks within each shelf must be distributed equally to both controllers of the HA pair.
With SSDs, a maximum of one disk shelf can be connected to one SAS stack to provide the required performance for the SAP HANA hosts, as shown in Figure 11. The disks within each shelf must be distributed equally to both controllers of the HA pair. With the DS224C disk shelf, quad-path SAS cabling can also be used but is not required.

**Aggregate Configuration**

In general, one aggregate per controller must be configured, independent of which disk shelf or disk technology (SSDs or HDDs) is used. For FAS9000 systems, two data aggregates are required for optimal performance.

**Aggregate Configuration with HDDs**

Figure 12 shows a configuration for eight SAP HANA hosts. Four SAP HANA hosts are attached to each storage controller. Two separate aggregates, one at each storage controller, are configured. Each aggregate is configured with $4 \times 10 = 40$ data disks (HDDs).
Aggregate Configuration with SDDs

Figure 13 shows a configuration for eight SAP HANA hosts using a DS224C disk shelf connected with 12Gb SAS. Four SAP HANA hosts are attached to each storage controller. Two separate aggregates, one at each storage controller, are configured. Each aggregate is configured with six data disks (SDDs).

Storage Virtual Machine Configuration

Multiple-host SAP landscapes with SAP HANA databases can use a single SVM. An SVM can also be assigned to each SAP landscape if necessary in case they are managed by different teams within a company. The screenshots and command outputs in this document use an SVM named hana.
Logical Interface Configuration

Within the storage cluster configuration, one network interface (LIF) must be created and assigned to a dedicated FCP port. If, for example, four FCP ports are required for performance reasons, four LIFs must be created. Figure 14 shows a screenshot of the eight LIFs (named `fc_hana-*`) that were configured on the `hana` SVM.

Figure 14) Logical interface configuration.

FCP Portsets

An FCP portset is used to define which LIFs are to be used by a specific initiator group. Typically, all LIFs created for the HANA systems are placed in the same port set. Figure 15 shows the configuration of a port set named "all" that includes the eight LIFs that were already created.
Initiator Groups

An initiator group can be configured for each server or for a group of servers that require access to a LUN. The initiator group configuration requires the worldwide port names (WWPNs) of the servers.

Using the `sanlun` tool, run the following command to obtain the WWPNs of each SAP HANA host:

```bash
stlrx300s8-6:~ # sanlun fcp show adapter
/sbin/udevadm
/sbin/udevadm

host0 ...... WWPN:2100000e1e163700
host1 ...... WWPN:2100000e1e163701
```

**Note:** The `sanlun` tool is part of the NetApp Host Utilities and must be installed on each SAP HANA host. More details can be found in section “Host Setup.”

Figure 16 shows the list of initiators for “server 6”. The initiator group contains all WWPNs of the server and is assigned to the port set of the storage controller.
Figure 16) Initiator groups.

Volume and LUN Configuration for SAP HANA Single-Host Systems

Figure 17 shows the volume configuration of four single-host SAP HANA systems. The data and log volumes of each SAP HANA system are distributed to different storage controllers. For example, volume SID1_data_mnt00001 is configured on controller A and volume SID1_log_mnt00001 is configured on controller B. Within each volume, a single LUN is configured.

Note: If only one storage controller of a high-availability (HA) pair is used for the SAP HANA systems, data volumes and log volumes can also be stored on the same storage controller.

Figure 17) Volume layout for SAP HANA multiple-host and single-host systems.
For each SAP HANA host, a data volume, a log volume, and a volume for `/hana/shared` are configured. Table 3 shows an example configuration with four SAP HANA single-host systems.

Table 3) Volume configuration for SAP HANA single-host systems.

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Aggregate at Controller A</th>
<th>Aggregate at Controller B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data, log, and shared volumes for system SID1</td>
<td>• Data volume: SID1_data_mnt00001</td>
<td>• Log volume: SID1_log_mnt00001</td>
</tr>
<tr>
<td></td>
<td>• Shared volume: SID1_shared</td>
<td></td>
</tr>
<tr>
<td>Data, log, and shared volumes for system SID2</td>
<td>• Log volume: SID2_log_mnt00001</td>
<td>• Data volume: SID2_data_mnt00001</td>
</tr>
<tr>
<td></td>
<td>• Shared volume: SID2_shared</td>
<td></td>
</tr>
<tr>
<td>Data, log, and shared volumes for system SID3</td>
<td>• Data volume: SID3_data_mnt00001</td>
<td>• Log volume: SID3_log_mnt00001</td>
</tr>
<tr>
<td></td>
<td>• Shared volume: SID3_shared</td>
<td></td>
</tr>
<tr>
<td>Data, log, and shared volumes for system SID4</td>
<td>• Log volume: SID4_log_mnt00001</td>
<td>• Data volume: SID4_data_mnt00001</td>
</tr>
<tr>
<td></td>
<td>• Shared volume: SID4_shared</td>
<td></td>
</tr>
</tbody>
</table>

Table 4 shows an example of the mount point configuration for a single-host system.

Table 4) Mount points for single-host systems.

<table>
<thead>
<tr>
<th>LUN</th>
<th>Mount Point at HANA Host</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>SID1_data_mnt00001</td>
<td>/hana/data/SID1/mnt00001</td>
<td>Mounted using <code>/etc/fstab</code> entry</td>
</tr>
<tr>
<td>SID1_log_mnt00001</td>
<td>/hana/log/SID1/mnt00001</td>
<td>Mounted using <code>/etc/fstab</code> entry</td>
</tr>
<tr>
<td>SID1_shared</td>
<td>/hana/shared/SID1</td>
<td>Mounted using <code>/etc/fstab</code> entry</td>
</tr>
</tbody>
</table>

Note: With the described configuration, the `/usr/sap/SID1` directory in which the default home directory of user SID1adm is stored, is on the local disk. In a disaster recovery setup with disk-based replication, NetApp recommends creating an additional LUN within the SID1_shared volume for the `/usr/sap/SID1` directory so that all file systems are on the central storage.

Volume and LUN Configuration for SAP HANA Multiple-Host Systems

Figure 18 shows the volume configuration of a 4+1 multiple-host SAP HANA system. The data volumes and log volumes of each SAP HANA host are distributed to different storage controllers. For example, the volume SID_data_mnt00001 is configured on controller A and the volume SID_log_mnt00001 is configured on controller B. One LUN is configured within each volume.

The `/hana/shared` volume must be accessible by all HANA hosts and is therefore exported by using NFS. Even though there are no specific performance KPIs for the `/hana/shared` file system, NetApp recommends using a 10Gb Ethernet connection.

Note: If only one storage controller of an HA pair is used for the SAP HANA system, data and log volumes can also be stored on the same storage controller.
For each SAP HANA host, a data volume and a log volume are created. The `/hana/shared` volume is used by all hosts of the SAP HANA system. Table 5 shows an example configuration for a 4+1 multiple-host SAP HANA system.

Table 5) Volume configuration for SAP HANA multiple-host systems.

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Aggregate at Controller A</th>
<th>Aggregate at Controller B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data and log volumes for host 1</td>
<td>Data volume: <code>SID_data_mnt00001</code></td>
<td>Log volume: <code>SID_log_mnt00001</code></td>
</tr>
<tr>
<td>Data and log volumes for host 2</td>
<td>Log volume: <code>SID_log_mnt00002</code></td>
<td>Data volume: <code>SID_data_mnt00002</code></td>
</tr>
<tr>
<td>Data and log volumes for host 3</td>
<td>Data volume: <code>SID_data_mnt00003</code></td>
<td>Log volume: <code>SID_log_mnt00003</code></td>
</tr>
<tr>
<td>Data and log volumes for host 4</td>
<td>Log volume: <code>SID_log_mnt00004</code></td>
<td>Data volume: <code>SID_data_mnt00004</code></td>
</tr>
<tr>
<td>Shared volume for all hosts</td>
<td>Shared volume: <code>SID_shared</code></td>
<td>N/A</td>
</tr>
</tbody>
</table>

Table 6 shows the configuration and the mount points of a multiple-host system with four active SAP HANA hosts.

Table 6) Mount points for multiple-host systems.

<table>
<thead>
<tr>
<th>LUN or Volume</th>
<th>Mount Point at SAP HANA Host</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>LUN: <code>SID_data_mnt00001</code></td>
<td><code>/hana/data/SID/mnt00001</code></td>
<td>Mounted using storage connector</td>
</tr>
<tr>
<td>LUN: <code>SID_log_mnt00001</code></td>
<td><code>/hana/log/SID/mnt00001</code></td>
<td>Mounted using storage connector</td>
</tr>
<tr>
<td>LUN: <code>SID_data_mnt00002</code></td>
<td><code>/hana/data/SID/mnt00002</code></td>
<td>Mounted using storage connector</td>
</tr>
<tr>
<td>LUN or Volume</td>
<td>Mount Point at SAP HANA Host</td>
<td>Note</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------------------------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>LUN: SID_log_mnt00002</td>
<td>/hana/log/SID/mnt00002</td>
<td>Mounted using storage connector</td>
</tr>
<tr>
<td>LUN: SID_data_mnt00003</td>
<td>/hana/data/SID/mnt00003</td>
<td>Mounted using storage connector</td>
</tr>
<tr>
<td>LUN: SID_log_mnt00003</td>
<td>/hana/log/SID/mnt00003</td>
<td>Mounted using storage connector</td>
</tr>
<tr>
<td>LUN: SID_data_mnt00004</td>
<td>/hana/data/SID/mnt00004</td>
<td>Mounted using storage connector</td>
</tr>
<tr>
<td>LUN: SID_log_mnt00004</td>
<td>/hana/log/SID/mnt00004</td>
<td>Mounted using storage connector</td>
</tr>
<tr>
<td>Volume: SID_shared</td>
<td>/hana/shared/SID</td>
<td>Mounted at all hosts using NFS and /etc/fstab entry</td>
</tr>
</tbody>
</table>

**Note:** With the described configuration, the `/usr/sap/SID` directory in which the default home directory of user SIDadm is stored is on the local disk for each HANA host. In a disaster recovery setup with disk-based replication, NetApp recommends creating four additional subdirectories in the `SID_shared` volume for the `/usr/sap/SID` file system so that each database host has all its file systems on the central storage.

**Volume Options**

The volume options listed in Table 7 must be verified and set on all SVMs.

**Table 7) Volume options.**

<table>
<thead>
<tr>
<th>Action</th>
<th>Clustered Data ONTAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disable automatic Snapshot copies</td>
<td><code>vol modify -vserver &lt;vserver-name&gt; -volume &lt;volname&gt; -snapshot-policy none</code></td>
</tr>
<tr>
<td>Disable visibility of Snapshot directory</td>
<td><code>vol modify -vserver &lt;vserver-name&gt; -volume &lt;volname&gt; -snapdir-access false</code></td>
</tr>
</tbody>
</table>

**Creating LUNs, Volumes, and Mapping LUNs to Initiator Groups**

You can use NetApp OnCommand System Manager to create storage volumes and LUNs and the map them to the initiator groups of the servers.

The following steps show the configuration of a 2+1 multiple-host HANA system with the SID FC2.

2. Enter the LUN name, select the LUN type, and enter the size of the LUN.

3. Enter the volume name and the hosting aggregate.
4. Select the initiator groups to which the LUNs should be mapped.

5. Provide the QoS settings.
6. Click Next on the Summary page.

7. Click Finish on the Completion page.
8. Repeat steps 2 to 7 for each LUN.

Figure 19 shows a summary of all LUNs that need to be created for 2+1 multiple-host setup.

**Figure 19) LUN summary.**

### 4.4 SAP HANA Storage Connector API

A storage connector is required only in multiple-host environments that have failover capabilities. In multiple-host setups, SAP HANA provides high-availability functionality so that an SAP HANA database host can fail over to a standby host. In this case, the LUNs of the failed host are accessed and used by
the standby host. The storage connector is used to make sure that a storage partition can be actively accessed by only one database host at a time.

In SAP HANA multiple-host configurations with NetApp storage, the standard storage connector delivered by SAP is used. The “SAP HANA FC Storage Connector Admin Guide” can be found as an attachment to SAP note 1900823.

### 4.5 Host Setup

Before setting up the host, NetApp SAN Host Utilities must be downloaded from the NetApp Support site and installed on the HANA servers. The Host Utility documentation includes information about additional software that must be installed depending on the FCP HBA used.

The documentation also contains information about multipath configurations that are specific to the Linux version used. This document covers the required configuration steps for SLES 15 and Red Hat Enterprise Linux 7.6, as described in the Linux Host Utilities 7.1 Installation and Setup Guide.

#### Configure Multipathing

**Note:** Steps 1 to 6 must be performed on all worker and standby hosts in the SAP HANA multiple-host configuration.

To configure multipathing, complete the following steps:

1. Run the Linux `rescan-scsi-bus.sh -a` command on each server to discover new LUNs.

2. Run the `sanlun show` command and verify that all required LUNs are visible. The following example shows the `sanlun lun show` command output for a 2+1 multiple-host HANA system with two data LUNs and two log LUNs. The output shows the LUNs and the corresponding device files, such as LUN FC2_data_mnt00001 and the device file `/dev/sdax`. Each LUN has eight FC paths from the host to the storage controllers.

3. Run the `multipath -r` command to get the worldwide identifiers (WWIDs) for the device file names:

   **Note:** In this example, there are four LUNs.

<table>
<thead>
<tr>
<th>lun-pathname</th>
<th>device filename</th>
<th>host adapter</th>
<th>protocol</th>
<th>size</th>
<th>product</th>
</tr>
</thead>
<tbody>
<tr>
<td>hana</td>
<td>/vol/FC2_data_mnt00001/FC2_data_mnt00001</td>
<td>dev/sdh</td>
<td>host11</td>
<td>FCP</td>
<td>1.2t</td>
</tr>
<tr>
<td>hana</td>
<td>/vol/FC2_data_mnt00001/FC2_data_mnt00001</td>
<td>dev/sda</td>
<td>host11</td>
<td>FCP</td>
<td>1.2t</td>
</tr>
<tr>
<td>hana</td>
<td>/vol/FC2_data_mnt00001/FC2_data_mnt00001</td>
<td>dev/sdc</td>
<td>host11</td>
<td>FCP</td>
<td>1.2t</td>
</tr>
<tr>
<td>hana</td>
<td>/vol/FC2_data_mnt00001/FC2_data_mnt00001</td>
<td>dev/sdb</td>
<td>host11</td>
<td>FCP</td>
<td>1.2t</td>
</tr>
<tr>
<td>hana</td>
<td>/vol/FC2_data_mnt00001/FC2_data_mnt00001</td>
<td>dev/sda</td>
<td>host11</td>
<td>FCP</td>
<td>1.2t</td>
</tr>
<tr>
<td>hana</td>
<td>/vol/FC2_data_mnt00001/FC2_data_mnt00001</td>
<td>dev/sdc</td>
<td>host11</td>
<td>FCP</td>
<td>1.2t</td>
</tr>
<tr>
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<td>dev/sdb</td>
<td>host11</td>
<td>FCP</td>
<td>1.2t</td>
</tr>
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<td>dev/sda</td>
<td>host11</td>
<td>FCP</td>
<td>1.2t</td>
</tr>
<tr>
<td>hana</td>
<td>/vol/FC2_data_mnt00001/FC2_data_mnt00001</td>
<td>dev/sdc</td>
<td>host11</td>
<td>FCP</td>
<td>1.2t</td>
</tr>
<tr>
<td>hana</td>
<td>/vol/FC2_data_mnt00001/FC2_data_mnt00001</td>
<td>dev/sdb</td>
<td>host11</td>
<td>FCP</td>
<td>1.2t</td>
</tr>
<tr>
<td>hana</td>
<td>/vol/FC2_data_mnt00001/FC2_data_mnt00001</td>
<td>dev/sda</td>
<td>host11</td>
<td>FCP</td>
<td>1.2t</td>
</tr>
<tr>
<td>hana</td>
<td>/vol/FC2_data_mnt00001/FC2_data_mnt00001</td>
<td>dev/sdc</td>
<td>host11</td>
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<td>hana</td>
<td>/vol/FC2_data_mnt00001/FC2_data_mnt00001</td>
<td>dev/sdb</td>
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</tr>
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<td>hana</td>
<td>/vol/FC2_data_mnt00001/FC2_data_mnt00001</td>
<td>dev/sda</td>
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</tr>
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<td>/vol/FC2_data_mnt00001/FC2_data_mnt00001</td>
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<td>hana</td>
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<td>host11</td>
<td>FCP</td>
<td>1.2t</td>
</tr>
<tr>
<td>hana</td>
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<td>dev/sdb</td>
<td>host11</td>
<td>FCP</td>
<td>1.2t</td>
</tr>
</tbody>
</table>
4. Edit the `/etc/multipath.conf` file and add the WWIDs and alias names.

   **Note:** The example output shows the content of the `/etc/multipath.conf` file, which includes alias names for the four LUNs of a 2+1 multiple-host system.

```bash
stlr300s8-6:~ # cat /etc/multipath.conf
multipaths {
    multipath {
        wwid    3600a09803800436375d4d42d753879
        alias   hana-FC2_data_mnt00001
    }
    multipath {
        wwid    3600a09803800436375d4d42d753878
        alias   hana-FC2_log_mnt00001
    }
    multipath {
        wwid    3600a09803800436375d4d42d753879
        alias   hana-FC2_data_mnt00002
    }
    multipath {
        wwid    3600a09803800436375d4d42d753878
        alias   hana-FC2_log_mnt00001
    }
```
5. Run the `multipath -r` command to reload the device map.

6. Verify the configuration by running the `multipath -ll` command to list all the LUNs, alias names, and active and standby paths.

   **Note:** The following example output shows the output of a 2+1 multiple-host HANA system with two data and two log LUNs.

```
stlrx300s8-6:~ # multipath -ll
hana-FC2_data_mnt00002 (3600a098038304436375d4d442d753879) dm-1 NETAPP,LUN C-Mode
size=1.2T features='4 queue_if_no_path pg_init_retries 50 retain_attached_hw_handler'
hwhandler='1 alua' wp=rw
    |-- policy='service-time 0' prio=50 status=enabled
    |   |-- 10:0:1:1 sdj 8:144 active ready running
    |   |-- 10:0:3:1 sdp 8:240 active ready running
    |   `-- 11:0:1:1 sdw 65:96 active ready running
        `-- policy='service-time 0' prio=10 status=enabled
            |-- 10:0:0:1 sdg 8:96 active ready running
            |-- 10:0:2:1 sdm 8:192 active ready running
            |-- 11:0:1:1 sdz 65:144 active ready running
            `-- 11:0:3:1 sdaf 65:240 active ready running
hana-FC2_log_mnt00002 (3600a098038304436392b4d442d6f5350) dm-1 NETAPP,LUN C-Mode
size=0.512G features='4 queue_if_no_path pg_init_retries 50 retain_attached_hw_handler'
hwhandler='1 alua' wp=rw
    |-- policy='service-time 0' prio=50 status=enabled
    |   |-- 10:0:0:3 sdi 8:128 active ready running
    |   |-- 10:0:2:3 sdf 8:224 active ready running
    |   `-- 11:0:0:3 sds 65:32 active ready running
        `-- policy='service-time 0' prio=10 status=enabled
            |-- 10:0:1:3 sdd 8:48 active ready running
            |-- 10:0:3:3 sdf 8:80 active ready running
            |-- 11:0:1:3 sds 65:32 active ready running
            `-- 11:0:2:3 sde 65:64 active ready running
hana-FC2_log_mnt00001 (3600a098038304436375d4d442d753878) dm-0 NETAPP,LUN C-Mode
size=0.512G features='4 queue_if_no_path pg_init_retries 50 retain_attached_hw_handler'
hwhandler='1 alua' wp=rw
    |-- policy='service-time 0' prio=50 status=enabled
    |   |-- 10:0:0:0 sdc 8:32 active ready running
    |   |-- 10:0:2:0 sde 8:64 active ready running
    |   `-- 11:0:1:0 sdt 65:48 active ready running
        `-- policy='service-time 0' prio=10 status=enabled
            |-- 10:0:1:0 sdd 8:48 active ready running
            |-- 10:0:3:0 sdf 8:80 active ready running
            |-- 11:0:0:0 sds 65:32 active ready running
            `-- 11:0:2:0 sdv 65:80 active ready running
```
Create File Systems

To create the XFS file system on each LUN belonging to the HANA system, take one of the following actions:

- For a single-host system, create the XFS file system on the data, log, and /hana/shared LUNs.

  ```bash
  stlrx300s8-6:/ # mkfs.xfs /dev/mapper/hana-FC2_data_mnt00001
  stlrx300s8-6:/ # mkfs.xfs /dev/mapper/hana-FC2_log_mnt00001
  stlrx300s8-6:/ # mkfs.xfs /dev/mapper/hana-FC2_shared
  ```

- For a multiple-host system, create the XFS file system on all data and log LUNs.

  ```bash
  stlrx300s8-6:/ # mkfs.xfs /dev/mapper/hana-FC2_log_mnt00001
  stlrx300s8-6:/ # mkfs.xfs /dev/mapper/hana-FC2_log_mnt00002
  stlrx300s8-6:/ # mkfs.xfs /dev/mapper/hana-FC2_data_mnt00001
  stlrx300s8-6:/ # mkfs.xfs /dev/mapper/hana-FC2_data_mnt00002
  ```

Create Mount Points

To create the required mount point directories, take one of the following actions:

- For a single-host system, set permissions and create mount points on the database host.

  ```bash
  stlrx300s8-6:/ # mkdir -p /hana/data/FC2/mnt00001
  stlrx300s8-6:/ # mkdir -p /hana/log/FC2/mnt00001
  stlrx300s8-6:/ # mkdir -p /hana/shared
  stlrx300s8-6:/ # chmod -R 777 /hana/log/FC2
  stlrx300s8-6:/ # chmod -R 777 /hana/data/FC2
  stlrx300s8-6:/ # chmod 777 /hana/shared
  ```

- For a multiple-host system, set permissions and create mount points on all worker and standby hosts.

  **Note:** The example commands show a 2+1 multiple-host HANA system.

  ```bash
  stlrx300s8-6:/ # mkdir -p /hana/data/FC2/mnt00001
  stlrx300s8-6:/ # mkdir -p /hana/log/FC2/mnt00001
  stlrx300s8-6:/ # mkdir -p /hana/data/FC2/mnt00002
  stlrx300s8-6:/ # mkdir -p /hana/log/FC2/mnt00002
  stlrx300s8-6:/ # mkdir -p /hana/shared
  stlrx300s8-6:/ # chmod -R 777 /hana/log/FC2
  stlrx300s8-6:/ # chmod -R 777 /hana/data/FC2
  stlrx300s8-6:/ # chmod 777 /hana/shared
  ```

Mount File Systems

To mount file systems during system boot using the `/etc/fstab` configuration file, complete the following steps:

1. Take one of the following actions:
   - For a single-host system, add the required file systems to the `/etc/fstab` configuration file.
     
     **Note:** The XFS file systems for the data LUN must be mounted with the `relatime` and `inode64` mount options. The XFS file systems for the log LUN must be mounted with the `relatime`, `inode64`, and `nobarrier` mount options.

     ```bash
     stlrx300s8-6:/ # cat /etc/fstab
     /dev/mapper/FAS8200-hana-FC2_shared /hana/shared xfs default 0 0
     /dev/mapper/FAS8200-hana-FC2_log_mnt00001 /hana/log/FC2/mnt00001 xfs relatime,inode64,nobarrier 0 0
     /dev/mapper/FAS8200-hana-FC2_data_mnt00001 /hana/data/FC2/mnt00001 xfs relatime,inode64 0 0
     ```
   - For a multiple-host system, add the /hana/shared file system to the `/etc/fstab` configuration file.

     **Note:** All the data and log file systems are mounted through the SAP HANA storage connector.
2. To mount the file systems, run the `mount -a` command.

### 4.6 I/O Stack Configuration for SAP HANA

Starting with SAP HANA 1.0 SPS10, SAP introduced parameters to adjust the I/O behavior and optimize the database for the file and storage system used.

NetApp conducted performance tests to define the ideal values. The following table lists the optimal values as inferred from the performance tests.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>max_parallel_io_requests</td>
<td>128</td>
</tr>
<tr>
<td>async_read_submit</td>
<td>on</td>
</tr>
<tr>
<td>async_write_submit_active</td>
<td>on</td>
</tr>
<tr>
<td>async_write_submit_blocks</td>
<td>all</td>
</tr>
</tbody>
</table>

For SAP HANA 1.0 up to SPS12, these parameters can be set during the installation of the SAP HANA database as described in SAP Note [2267798 – Configuration of the SAP HANA Database during Installation Using hdbparam](https://help.sap.com/doc/2267798/1.0/en-US/

Alternatively, the parameters can be set after the SAP HANA database installation using the `hdbparam` framework.

```
fc2adm@stlrx300s8-6:/usr/sap/FC2/HDB00> hdbparam --paramset fileio.max_parallel_io_requests=128
fc2adm@stlrx300s8-6:/usr/sap/FC2/HDB00> hdbparam --paramset fileio.async_write_submit_active=on
fc2adm@stlrx300s8-6:/usr/sap/FC2/HDB00> hdbparam --paramset fileio.async_read_submit=on
fc2adm@stlrx300s8-6:/usr/sap/FC2/HDB00> hdbparam --paramset fileio.async_write_submit_blocks=all
```

Starting with SAP HANA 2.0, `hdbparam` is deprecated and the parameters have been moved to `global.ini`. The parameters can be set using SQL commands or SAP HANA Studio. See SAP Note [2399079 - Elimination of hdbparam in HANA 2](https://help.sap.com/doc/2399079/1.0/en-US/) for details.

### 4.7 SAP HANA Software Installation

#### Install on Single-Host System

SAP HANA software installation does not require any additional preparation for a single-host system.

#### Install on Multiple-Host System

**Note:** The following installation procedure is based on SAP HANA 1.0 SPS12 or later.

Before beginning the installation, create a `global.ini` file to enable use of the SAP storage connector during the installation process. The SAP storage connector mounts the required file systems at the worker hosts during the installation process. The `global.ini` file must be available in a file system that is accessible from all hosts, such as the `/hana/shared/SID` file system.

Before installing SAP HANA software on a multiple-host system, the following steps must be completed:

1. Add the following mount options for the data LUNs and the log LUNs to the `global.ini` file:
   - `relatime` and `inode64` for the data file system
   - `relatime`, `inode64`, and `nobarrier` for the log file system
2. Add the WWIDs of the data and log partitions. The WWIDs must match the alias names configured in the `/etc/multipath.conf` file.
The following output shows an example of a 2+1 multiple-host setup in which the system identifier (SID) is FC2.

```
[communication]
listeninterface = .global

[persistence]
basepath_datavolumes = /hana/data/FC2
basepath_logvolumes = /hana/log/FC2

[storage]
ha_provider = hdb_ha.fcClient
partition_*_*__prtype = 5
partition_*_data__mountoptions = -o relatime,inode64
partition_*_log__mountoptions = -o relatime,inode64,nobarrier
partition_1_data__wwid = hana-FC2_data_mnt00001
partition_1_log__wwid = hana-FC2_log_mnt00001
partition_2_data__wwid = hana-FC2_data_mnt00002
partition_2_log__wwid = hana-FC2_log_mnt00002

[system_information]
usage = custom

[trace]
ha_fcclient = info
```

3. Using the SAP hdblcm installation tool, start the installation by running the following command at one of the worker hosts. Use the addhosts option to add the second worker (stlrx300s8-7) and the standby host (stlrx300s8-8).

**Note:** The directory where the prepared `global.ini` file has been stored is included with the `storage_cfg` CLI option (`--storage_cfg=/hana/shared`).

```
SAP HANA Lifecycle Management - SAP HANA Database 2.00.030.00.1522209842
************************************************************************
Scanning software locations...
Detected components:
SAP HANA Database (2.00.030.00.1522209842) in /mnt/hwval/Software/SAP-Installation/HANA-DB-20SPS3/51053061/DATA_UNITS/HDB_SERVER_LINUX_X86_64/server
SAP HANA AFL (incl.PAL,BFL,OFL) (2.00.030.0001.1522234444) in /mnt/hwval/Software/SAP-Installation/HANA-DB-20SPS3/51053061/DATA_UNITS/HDB_AFL_LINUX_X86_64/packages
SAP HANA EML AFL (2.00.030.0001.1522234444) in /mnt/hwval/Software/SAP-Installation/HANA-DB-20SPS3/51053061/DATA_UNITS/HDB_EML_AFL_LINUX_X86_64/packages
SAP HANA EPM-MDS (2.00.030.0001.1522234444) in /mnt/hwval/Software/SAP-Installation/HANA-DB-20SPS3/51053061/DATA_UNITS/SAP_HANA_EPM_MDS_LINUX_X86_64/packages
SAP HANA Database Client (2.3.78.1521836270) in /mnt/hwval/Software/SAP-Installation/HANA-DB-20SPS3/51053061/DATA_UNITS/HDB_CLIENT_LINUX_X86_64/client
SAP HANA Studio (2.3.35.000000) in /mnt/hwval/Software/SAP-Installation/HANA-DB-20SPS3/51053061/DATA_UNITS/HDB_STUDIO_LINUX_X86_64/studio
SAP HANA Smart Data Access (2.00.3.0000) in /mnt/hwval/Software/SAP-Installation/HANA-DB-20SPS3/51053061/DATA_UNITS/HDB_SDA_LINUX_X86_64/packages
SAP HANA XS Advanced Runtime (1.0.82.303870) in /mnt/hwval/Software/SAP-Installation/HANA-DB-20SPS3/51053061/DATA_UNITS/XSA_RT_LINUX_X86_64/packages
GUI for HALM for XSA (including product installer) Version 1 (1.12.5) in /mnt/hwval/Software/SAP-Installation/HANA-DB-20SPS3/51053061/DATA_UNITS/XSACONTENT_10/XSACALMGUI12_5.zip
XSAC FILEPROCESSOR 1.0 (1.000.22) in /mnt/hwval/Software/SAP-Installation/HANA-DB-20SPS3/51053061/DATA_UNITS/XSACONTENT_10/XSACFILEPROC00_22.zip
```
SAP HANA Database version '2.00.030.00.1522209842' will be installed.

Select additional components for installation:

<table>
<thead>
<tr>
<th>Index</th>
<th>Components</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>all</td>
<td>All components</td>
</tr>
<tr>
<td>2</td>
<td>server</td>
<td>No additional components</td>
</tr>
<tr>
<td>3</td>
<td>client</td>
<td>Install SAP HANA Database Client version 2.3.78.1521836270</td>
</tr>
<tr>
<td>4</td>
<td>studio</td>
<td>Install SAP HANA Studio version 2.3.35.000000</td>
</tr>
<tr>
<td>5</td>
<td>smartda</td>
<td>Install SAP HANA Smart Data Access version 2.00.3.000.0</td>
</tr>
<tr>
<td>6</td>
<td>xs</td>
<td>Install SAP HANA XS Advanced Runtime version 1.0.82.303870</td>
</tr>
<tr>
<td>7</td>
<td>afl</td>
<td>Install SAP HANA AFL (Incl.PAL,BFL,OFL) version 2.00.030.0001.1522223444</td>
</tr>
<tr>
<td>8</td>
<td>eml</td>
<td>Install SAP HANA EML AFL version 2.00.030.0001.1522223444</td>
</tr>
<tr>
<td>9</td>
<td>epmmds</td>
<td>Install SAP HANA EPM-MDS version 2.00.030.0001.1522223444</td>
</tr>
</tbody>
</table>

Enter comma-separated list of the selected indices [3]: 2,3

4. Verify that the installation tool installed all selected components at all worker and standby hosts.

Where to Find Additional Information

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

- Best Practices and Recommendations for Scale-Up Deployments of SAP HANA on VMware vSphere

- Best Practices and Recommendations for Scale-Out Deployments of SAP HANA on VMware vSphere

- SAP Certified Enterprise Storage Hardware for SAP HANA

- SAP HANA Storage Requirements
  [http://go.sap.com/documents/2015/03/74db55a-5a7c-0010-82c7-ed7a71af511fa.html]

- SAP HANA Tailored Data Center Integration Frequently Asked Questions
  [https://www.sap.com/documents/2016/05/e8705aae-717c-0010-82c7-ed7a71af511fa.html]

- TR-4646: SAP HANA Disaster Recovery with Asynchronous Storage Replication Using SnapCenter 4.0 SAP HANA Plug-In
  [https://www.netapp.com/us/media/tr-4646.pdf]
- TR-4614: SAP HANA Backup and Recovery with SnapCenter
- TR-4338: SAP HANA on VMware vSphere with NetApp FAS and AFF Systems
- TR-4667: Automating SAP System Copies Using the SnapCenter 4.0 SAP HANA Plug-in
- NetApp Documentation Centers
- NetApp FAS Storage System Resources
  https://mysupport.netapp.com/info/web/ECMLP2676498.html
- SAP HANA Software Solutions

Version History

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Document Version History</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version 1.0</td>
<td>February 2015</td>
<td>Initial version</td>
</tr>
<tr>
<td>Version 2.0</td>
<td>October 2015</td>
<td>Included I/O parameters for SAP HANA and HWVAL SPS 10 and later</td>
</tr>
<tr>
<td>Version 2.1</td>
<td>February 2016</td>
<td>Updated capacity sizing</td>
</tr>
<tr>
<td>Version 3.0</td>
<td>February 2017</td>
<td>New NetApp storage systems and disk shelves</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New features of ONTAP 9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New OS releases (SLES12 SP1 and Red Hat Enterprise Linux 7.2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New SAP HANA release</td>
</tr>
<tr>
<td>Version 3.1</td>
<td>July 2017</td>
<td>Minor updates</td>
</tr>
<tr>
<td>Version 4.0</td>
<td>September 2018</td>
<td>New NetApp storage systems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New OS releases (SLES12 SP3 and Red Hat Enterprise Linux 7.4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Additional minor updates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SAP HANA 2.0 SPS3</td>
</tr>
<tr>
<td>Version 4.1</td>
<td>September 2019</td>
<td>New OS releases</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minor updates</td>
</tr>
</tbody>
</table>
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