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Introduction

SAP® and partner solutions that use the market-leading SAP® HANA™ in-memory data platform enable businesses to run in real-time. Optimized for both transactional and analytical processing, SAP HANA solutions can dramatically accelerate analytics, business processes, sentiment data processing, and predictive capabilities. SAP HANA solutions also allow businesses to analyze Big Data rapidly, and this drives rapid innovation.

The SAP HANA database manages data in a multi core architecture for data distribution across all cores to maximize RAM locality by using scale-out (horizontally) and scale-up (vertically) functionality. Scale-up systems offer scalability, flexibility, and they enable CPU, memory, and storage to grow independently of one another as your needs expand.

When the SAP HANA platform is powered using the VMware® vSphere™ virtualization and cloud computing platform, it delivers a new deployment architecture to SAP HANA customers. The SAP HANA with VMware solution provides SAP customers with a data center platform that provides for agility, high availability, cost savings, and easy provisioning. This solution gives SAP customers the ability to provision instances of SAP HANA in virtual machines faster.

Using the SAP HANA platform with VMware vSphere virtualization infrastructure provides an optimal environment for achieving a unique, cost effective solution. The SAP HANA with VMware solution is enabled using VMware vSphere® vMotion®, VMware vSphere® Distributed Resource Scheduler™ (DRS), and VMware vSphere® High Availability (HA), and this ensures the best operational performance and availability.

This paper describes a best practices approach and recommendations for configuring, deploying, and optimizing SAP HANA scale-up deployments that run on VMware virtualization infrastructure. Many of the findings in this document are a result of joint testing conducted by VMware® and SAP® to characterize the performance of SAP HANA scale-up deployments, powered by VMware vSphere 5.5.

This paper is written for architects, engineers, and administrators, who are responsible for configuring and deploying the SAP HANA platform in a VMware virtualization environment. It assumes that the reader has a basic knowledge of VMware vSphere concepts and features, and SAP HANA and related SAP products and technologies.

Production Support

In November 2012, SAP announced initial support for SAP HANA on vSphere 5.1 for non-production environments. In April 2014, SAP extended this support to SAP HANA Scale-up production environments, including SAP Tailored Center Integration deployments.

VMware can support SAP HANA Scale-up databases, up to a total of 1 TB RAM. A 1 TB SAP HANA database is comprised of approximately 512 GB of compressed data. The remainder of the RAM is utilized for temporary tables, intermediate calculations, and other SAP HANA database structures. Sizing SAP HANA on vSphere is no different than the physical requirements.

Enabling Products and Technologies

The key enabling products and technologies for the SAP HANA with VMware solution include the SAP® HANA™ SP07 platform and the VMware® vSphere™ 5.5 platform. In particular, this solution uses the VMware vSphere advanced features including vMotion, VMware Distributed Resource Scheduler, and VMware High Availability. Each of these products and technologies is described in the sections that follow.

SAP HANA

SAP and partner solutions that use the market-leading SAP HANA in-memory data platform enable businesses to run in real-time. SAP HANA is an in-memory data platform that is deployable as an on-premise appliance or in the cloud. It is a revolutionary platform that is best suited for performing real-time analytics and developing and deploying real-time applications.
SAP HANA platform converges database and application platform capabilities in-memory to transform transactions, analytics, text analysis, predictive, and spatial processing to enable businesses to operate in real-time. At the core of this real-time data platform is the SAP HANA database. The SAP HANA database is fundamentally different from any other database engine in the market today, as described below.

The SAP HANA platform is most suitable for building and deploying next-generation, real-time applications and analytics. Its architecture enables converged, online transaction processing (OLTP) and online analytical processing (OLAP) within a single in-memory, column-based data store using the ACID (Atomicity, Consistency, Isolation, Durability) compliance model, and it eliminates data redundancy and latency.

SAP HANA provides advanced capabilities that dramatically accelerate predictive text analytics, spatial processing, business analytics, and data virtualization, all on the same architecture. It also simplifies application development and rapid processing across Big Data sources and structures, and this drives innovation.

SAP HANA is well-suited for scenarios where businesses need to:

- Go deep within their data sets to ask complex and interactive questions.
- Go broad (this means working with enormous data sets that are of different types and from different sources) at the same time.

Increasingly, there is a need for this data to be recent and preferably in real-time.

In addition, businesses require this scenario to be performed at high speed (very fast response time and true interactivity). All without any pre-fabrication (no data preparation, no pre-aggregates, and no tuning).

In this type of scenario, only SAP HANA is well suited to address this unique set of requirements effectively. In fact, SAP HANA is at its best when fulfilling these requirements, or any subset these needs, in any combination.
Real-time Analytics

Examples of the real-time analytics SAP HANA can perform include:

• **Operational reporting.** Provides real-time insights from transaction systems such as custom or SAP ERP.

• **Data warehousing (SAP NetWeaver BW on HANA).** BW customers can run their entire BW application on the SAP HANA platform, leading to unprecedented BW performance. For example, queries run 10 to 100 times faster, data loads 5 to 10 times faster, and calculations run 5 to 10 times faster.

• **Predictive and text analysis on Big Data.** SAP HANA provides the ability to perform predictive and text analysis on large volumes of data in real-time using its in-database predictive algorithms and its R integration capability. SAP HANA text search/analysis capabilities provide a robust way to take advantage of unstructured data.

Real-time Applications

Examples of the real-time applications SAP HANA can perform include:

• **Core process accelerators.** Accelerate business reporting by using ERP Accelerators. They provide non-disruptive ways to take advantage of in-memory technology.

• **Planning, optimization applications.** SAP HANA excels at applications that require complex scheduling with fast results, and SAP is delivering solutions that no other vendor can match.

• **Sense and response applications.** These applications offer real-time insights on Big Data such as smart meter data, point-of-sale data, social media data, and more. They involve complexities such as personalized insight and recommendations, text search and mining, and predictive analytics. Typically, these processes are data-intensive, and many of these processes could not be deployed in the past due to cost and performance constraints.

OLTP Workloads

In addition to real-time analytic workloads (OLAP), HANA is well suited to run traditional online transaction processing (OLTP) workloads. With SAP Business Suite on HANA (SoH), SAP supports SAP HANA to run the SoH workload, in addition to regular databases in an integrated scenario. With SoH, scenarios that used to be performed on a relational database are now performed exclusively on a SAP HANA database. This enables the existing and optimized functions on an SAP HANA database to be used, instead of separating the analytics from the online processing.

For detailed SAP HANA information, see the SAP HANA Platform at: https://help.sap.com/hana_platform

SAP HANA Tailored Datacenter Integration (TDI)

The SAP HANA Tailored Datacenter Integration option, also called TDI, allows customers to use certain parts of their existing hardware and infrastructure components for the SAP HANA environment. Typically, a SAP HANA appliance comes with all of the necessary components pre-configured, as provided by certified SAP HANA hardware partners. TDI targets the usage of certain hardware and infrastructure components that might already exist in a customer’s landscape, instead of using the corresponding components that are delivered with a HANA appliance.

Depending on the existing data center layout, the SAP HANA TDI can:

• Reduce hardware and operational costs by reusing existing hardware components and operation processes.

• Mitigate risks and optimize time-to-value by enabling existing IT management processes for the SAP HANA implementation.

• Deliver more flexibility in hardware vendor selection by making the best use of the existing ecosystem.

The SAP HANA TDI framework becomes available as follows:

• Storage is the first layer that was opened to TDI deployment. It has been generally available since November 2013. The pilot program for the network layer started in the fourth quarter of 2013.

• Since many VMware features required shared storage TDI, the VMware platform follows the preferred deployment model.

For more information, go to the “Resources” section (SAP HANA References) near the end of this paper.
SAP HANA Appliance Model
SAP HANA appliance is a flexible, multi-purpose, data-source-agonistic in-memory appliance that combines SAP software components optimized to run on Intel-based hardware delivered by SAP’s leading partners such as Dell, Cisco, IBM, HP, and Fujitsu. It includes a number of integrated SAP software components including the SAP HANA database, real-time replication services, data services, data and lifecycle management, support for multiple interfaces based on industry standards and easy to use data modeling tool called SAP HANA studio.

The SAP HANA appliance delivers the following capabilities:

• Single SAP HANA database with native support for row and columnar data stores, providing full ACID (atomicity, consistency, isolation, durability) transactional capabilities.
• Powerful and flexible data calculation engine.
• SQL and MDX interfaces.
• Unified information modeling design environment.
• Data repository to persist views of business information (yes you can pull the power plug and your information is safely stored!)
• Data integration capabilities for accessing SAP (SAP NetWeaver BW, ERP, etc.) and non-SAP data sources.
• Integrated lifecycle management capabilities.
• Low TCO, as it is optimized for commodity hardware from a large number of partners.

Combined, these capabilities allow SAP HANA to support massive amounts of data from across the enterprise, and apply complex calculations that, in turn, allow decision-makers to explore and analyze vast amounts of information at incredible response times and with a high degree of flexibility, without the need for IT involvement or hand-holding.

VMware vSphere
VMware vSphere is an optimal virtualization platform and an enabling technology for cloud computing architectures. vSphere enables IT to meet service level agreements (SLAs) for the most demanding business-critical applications at the lowest total cost of ownership (TCO). VMware vSphere delivers control over all IT resources with the highest efficiency and choice in the industry, as shown below.

VMware vSphere virtualization solutions provide for:

• Consolidation. VMware virtualization allows multiple application servers to be consolidated onto one physical server, with little or no decrease in overall performance. This helps to minimize or eliminate underutilized server hardware, software, and infrastructure.
Best Practices and Recommendations for Scale-up Deployments of SAP HANA on VMware vSphere

• **Manageability.** The live migration of virtual machines from server to server and the associated storage is performed with no downtime using VMware vSphere® vMotion®, which simplifies common operations such as hardware maintenance, and VMware vSphere® Storage vMotion®.

• **Availability.** High availability can be enabled to reduce unplanned downtime and enable higher service levels for applications. VMware vSphere® High Availability (HA) ensures that, in the event of an unplanned hardware failure, the affected virtual machines are automatically restarted on another host in a VMware cluster.

• **Automation.** VMware automated load balancing takes advantage of vMotion and Storage vMotion to migrate virtual machines 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 virtual machines 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.

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. It implements each environment with its own set of hardware resources.

For more information about vSphere, see the “Resources” section near the end of this paper.
VMware vMotion (Live Migration)

VMware vMotion enables the live migration of running virtual machines from one physical server to another with zero
downtime, continuous service availability, and complete transaction integrity. vMotion is a key enabling technology
for creating the dynamic, automated, and self-optimizing data center. This capability makes hardware maintenance
possible at any time, and vMotion does not require clustering or redundant servers, as described below.

- Moves entire running virtual machines instantly. It performs live migrations with zero downtime, undetectable
to the user.
- Manages and schedules live migrations with ease at pre-defined times, without an administrator’s presence,
  and with the reliability and manageability that is derived from a production-proven product.
- Performs multiple concurrent migrations of a virtual machine running any operating system, across any type
  of hardware and storage that is supported by vSphere, complete with an audit trail.
- Moves online workloads from one ESXi® server host machine to another in order to maintain service levels
  and performance goals.
- Continuously and automatically optimizes virtual machine placement within resource pools. Proactively moves
  virtual machines away from failing or underperforming servers.
- Performs hardware maintenance without the need to schedule downtime and disrupt business operations.

The entire state of a virtual machine is encapsulated by a set of files that are stored on shared storage, such as
Fibre Channel or iSCSI Storage Area Network (SAN) or Network Attached Storage (NAS). VMware storage
Virtual Machine File System (VMFS) allows multiple installations of VMware ESXi to access the same virtual
machine files concurrently.

The active memory and precise execution state of the virtual machine is rapidly transferred over a high speed
network. This allows the virtual machine to instantaneously switch from running on the source ESXi host to the
destination ESXi host. vMotion keeps the transfer period imperceptible to users by keeping track of on-going
memory transactions in a bitmap.

Once the entire memory and system state has been copied over to the target ESXi host, vMotion suspends the
source virtual machine, copies the bitmap to the target ESXi host, and resumes the virtual machine on the target
ESXi host. The networks being used by the virtual machine are also virtualized by the underlying ESXi host, ensuring
that, even after migration, the virtual machine network identity and network connections are preserved.

vMotion manages the virtual MAC address as part of the process. Once the destination machine is activated, vMotion
pings the network router to ensure that it is aware of the new physical location of the virtual MAC address. Since
the migration of a virtual machine with vMotion preserves the precise execution state, the network identity, and
the active network connections, the result is zero downtime and no disruption to the users.
Migrating SAP HANA Databases with VMware vMotion

vMotion can migrate live SAP HANA databases from one host to another with no downtime. In the event that a SAP HANA host experiences increased hardware alerts, a basic administrator, database administrator, or virtual infrastructure administrator can proactively migrate the SAP HANA databases that reside on the host to another vSphere host, in order to avoid downtime or costs to the business.

SAP HANA runs in-memory and it has a large memory footprint. When executing a live migration, vMotion preserves the entire state of the SAP HANA memory, while query or transaction processing continues, with only a slight performance hit, until the migration is completed.

In contrast, a restart of SAP HANA:

• Query or transactions processing to abort.
• Temporary tables and computations to be lost.
• SAP HANA to perform a lazy restart by loading the system tables.
• Then columns can be preloaded, or upon query, into memory from disk.

Note: In order to avoid time stamp counter (TSC) issues when migrating virtual machines, the source and target ESXi host servers are required to use the same CPU type and frequency.

<table>
<thead>
<tr>
<th>OPTION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>High priority</td>
<td>vCenter Server reserves resources on both the source and destination hosts to maintain virtual machine availability during the migration. High priority migrations do not proceed if resources are unavailable.</td>
</tr>
<tr>
<td>Low priority</td>
<td>vCenter Server does not reserve resources on the source and destination hosts to maintain availability during the migration. Low priority migrations always proceed. However, the virtual machine might become briefly unavailable if host resources are unavailable during the migration.</td>
</tr>
</tbody>
</table>

Table 1: vMotion migration policies

SAP HANA production virtual machines are configured with memory and CPU reservations. When sufficient resources are not available on the destination host, vMotion cannot succeed. This is the exactly the behavior necessary for managing SAP HANA on vSphere in order to maintain performance levels.

VMware Distributed Resource Scheduler

VMware Distributed Resource Scheduler is an automated load balancing technology that aligns resource usage with business priority. DRS dynamically aligns resources with business priorities, balances computing capacity, and reduces power consumption in the data center, as shown below.
It takes advantage of vMotion to migrate virtual machines among a set of ESX hosts. DRS continuously monitors utilization across vSphere servers and intelligently allocates the available resources among virtual machines according to business needs.

DRS enables automatic initial virtual machine placement on any of the hosts in the cluster. It also makes automatic resource relocation and optimization decisions as hosts and virtual machines are added or removed from the cluster. When DRS is configured for manual control, it makes recommendations for review and later implementation only (there is no automated activity).

**Managing SAP HANA Landscapes Using VMware DRS**

SAP HANA landscapes can be managed using DRS. By using the DRS automation modes and rules that are described below, DRS can maximize the hardware investment and host resources, while maintaining enterprise SLAs in the SAP HANA landscape.

DRS can be set to these automation modes:

- **Manual.** In this mode, DRS recommends the initial placement of a virtual machine within the cluster, and then recommends the migration.
- **Semi-automated.** In this mode, DRS automates the placement of virtual machines and then recommends the migration of virtual machines.
- **Fully automated.** In this mode, DRS placements and migrations are automatic.

When deploying SAP HANA databases, it is essential to have DRS rules in place in order to avoid unwanted migrations:

- As an example, a cluster can include up to 32 hosts. If the cluster contains only three hosts that are SAP HANA-certified servers, DRS could potentially move SAP HANA to a non-certified host. In this case, DRS should be set with an Affinity rule that allows DRS to migrate SAP HANA only to a SAP HANA-certified host server.
- DRS can also be used to set an Anti-Affinity rule to enforce that, at the end of month, SAP HANA is the only virtual machine that can run on a particular vSphere host. This rule can also include a condition that only one instance of SAP HANA can run on a host.

If DRS rules are not in place when the data management system is first commissioned, place DRS in Manual mode to prevent an automatic vMotion operation that could place SAP HANA on an unsupported non-certified server.

**VMware High Availability**

VMware High Availability (HA) provides cost effective high availability for applications running in virtual machines. In the event of physical server failure, affected virtual machines are automatically restarted on other production servers with spare capacity. In the case of an operating system failure, VMware HA restarts the affected virtual machine on the same physical server. The combination of VMware HA and the other availability features of the VMware vSphere platform gives IT organizations the ability to select and easily deliver the level of availability required for all of their important applications.

VMware HA allows IT organizations to:

- Minimize unplanned downtime and IT service disruptions, while eliminating the need for dedicated standby hardware and the installation of additional software.
- Provide affordable uniform high availability across the entire virtualized IT environment, without the cost and complexity of failover solutions that are tied to either operating systems or specific applications.
This section describes the use cases and limitations of SAP HANA high availability and VMware High Availability features. It also describes the combinations of the SAP HANA high availability and VMware HA features that can be used together.

In addition to backup and restore functions, SAP HANA provides for built-in high availability. For more information on SAP HANA high availability, see “Introduction to High Availability for SAP HANA” at: http://www.saphana.com/docs/DOC-2775.

VMware HA is easy to use and it provides for high availability that is already sufficient for many IT organizations and their SAP HANA installations. VMware HA commonly achieves 99.9% of SAP HANA instance availability1. During failover, SAP HANA databases running on vSphere virtual machines can be prioritized to restart on designated hosts within a cluster. A dedicated standby server is not required. However, SAP HANA databases can only run on SAP HANA-certified servers, and DRS rules must be in place when using VMware HA, as described in the preceding section, “Managing SAP HANA Landscapes Using VMware DRS”. In vSphere 5.5, DRS rules are preserved when a VMware HA event occurs.

VMware HA is only able to detect and react on virtual machine operating system or VMware vSphere host hardware failures that negatively affect VMware HA protected virtual machines.

In contrast, SAP HANA provides specific high availability solutions that can be used in combination with VMware HA to protect a SAP HANA instance on every level.

SAP HANA System Replication2 is an alternative HA solution for SAP HANA that provides an extremely short recovery time objective (RTO). SAP HANA System Replication can get configured with or without data preload. As of today, only scale-up, single SAP HANA instance virtual machines are supported.

Following table summarizes the various high availability solutions that are available for a virtualized SAP HANA system on VMware vSphere.

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1 http://itblog.emc.com/2014/01/30/why-emc-it-virtualized-sap-hana-with-vmware/
<table>
<thead>
<tr>
<th>HIGH AVAILABILITY SOLUTION</th>
<th>VMWARE HIGH AVAILABILITY*</th>
<th>VMWARE SITE RECOVERY MANAGER</th>
<th>HANA SYSTEM REPLICATION</th>
<th>HANA HOST AUTO-FAILOVER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating system failures</td>
<td>Yes</td>
<td>–</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hardware failures</td>
<td>Yes</td>
<td>–</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Application failures</td>
<td>No</td>
<td>–</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>IP Redirect / DNS update</td>
<td>Not necessary</td>
<td>–</td>
<td>No, third-party software such as cluster software; Site Recovery Manager needed</td>
<td>-</td>
</tr>
<tr>
<td>Site failover</td>
<td>No</td>
<td>Yes, with third-party storage replication</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>RTO</td>
<td>Short</td>
<td>Medium</td>
<td>Shortest to medium RTO, depending IP redirect solution</td>
<td>Short</td>
</tr>
</tbody>
</table>

Supported with:
- VMware Site Recovery Manager; SAP HANA System Replication; Third-party cluster solutions**
- VMware High Availability; Third-party storage replication
- VMware High Availability
- HANA System Replication


** For more information, see the VMware In-guest cluster solution limitations outlined in “High Availability Solutions for SAP on VMware” at: [http://scn.sap.com/docs/DOC-32023](http://scn.sap.com/docs/DOC-32023)

Table 2: High availability solutions for SAP HANA on VMware vSphere

The SAP HANA built-in high availability features can be combined with VMware HA. For this reason, SAP HANA can be protected at any level. When combining VMware and SAP HANA HA solutions it must be ensured that only one solution gets used per protected feature. Overlapping may block the HA process in the case of a failure. Although operation features like VMware DRS must be configured to respect the HA concept, e. g. so it has to be ensured that DRS does not automatically move a running SAP HANA VM to a VMware ESXi host, on which already the HANA System Replication VM is running on. To automatically start SAP HANA after a high availability or reboot event, it is necessary to add the automatic SAP HANA start parameter to the SAP HANA configuration file. For more information, see the “SAP HANA Master Guide” at: [http://www.sap.com/docs/DOC-3817](http://www.sap.com/docs/DOC-3817).

Following figure shows a HANA HA concept that combines VMware HA and SAP HANA System Replication. With this solution vSphere Host or VM OS issues can get solved locally and in the rare event of a complete data center disaster, the SAP HANA instance can get restarted on another VM running on a VMware vSphere host that is placed in a remote, data center.

The VM marked as HANA* is the re-started SAP HANA VM that ran on Host A. When VMware HA detects a failure and is unable to restart the VM on Host A, the SAP HANA VM will automatically get restarted on Host B. While the SAP HANA instance is running, it replicates the HANA database logs to the HANA replica VM running on Host C. In an event that affects the whole datacenter A, the SAP HANA instance can get restarted from this replica. Restarting the SAP HANA database in the remote data center C must get initiated manually to have full control of the remote restart process and to ensure that there is no conflict with the automated VMware HA restart process.
SAP HANA Clones and Template

After a virtual SAP HANA database is installed, a VMware template or clone can be created with the SUSE Linux operating system already configured and tuned, pre-loaded with all of the necessary drivers, and with any additional software that is optimized to run on vSphere.

vSphere can enable copies of a SAP HANA virtual machine using either a VMware clone or a VMware template. A VMware clone is an exact copy of a SAP HANA virtual machine. When a virtual machine is cloned, a copy of the entire virtual machine is created, including its settings, any configured virtual devices, installed software, and other contents of the virtual machine’s disks. Optionally, guest operating system customization can be used to change some of the properties of the clone, such as the vSphere host name and networking settings.

In contrast to VMware clones, which are exact copies of a virtual machine, a VMware Snapshot represents the state of a virtual machine at the time it was taken, and it might negatively affect the performance of the virtual machine. This is based on how long it has been in place and how much the virtual machine and its guest operating system have changed since the time it was taken. Snapshots are not supported in production SAP HANA environments.

A VMware template is recommended once the SAP HANA database is fully configured and optimized for vSphere. A VMware template is a master copy of a SAP HANA virtual machine that can be used to create many SAP HANA clones. This template can be used to create and provision multiple SAP HANA virtual machines. Templates cannot be powered on or edited. A template offers a more secure way of preserving repeatable SAP HANA virtual machine configurations for deployment.

VMware Host Profiles

A VMware Host Profile encapsulates a reference host configuration and turns it into a profile or template that can then be applied across new or existing vSphere hosts. Administrators can use a Host Profile to ensure that all vSphere host configurations are consistent, and that configuration drifts can be easily prevented through automatic compliance checks.

Checking compliance on a regular basis ensures that the host or cluster continues to be correctly configured. Once the profile to a host or cluster is attached, it can be used to check the compliance status from various places in the vSphere Client.
In addition, when firmware upgrades or other events occur that require storage, network, or security configuration changes on multiple hosts in a cluster, administrators can edit the Host Profile and apply it across the cluster for consistent configuration updates.

When creating SAP HANA landscapes, it is critical for all SAP HANA virtual machines to be optimized and consistently configured. The hosts must also be optimized and configured consistently. Using VMware clones and templates to create the SAP HANA environment ensures that deployments are rapid and consistent and achieve consistent performance levels.

**SAP HANA Database Consolidation**

With VMware vSphere 5.5, customers can create virtual machines of up to 1 TB or large SAP HANA databases. vSphere 5.5 can also address up to 4 TB of RAM on each host, which allows customers to consolidate many SAP HANA databases of varying sizes onto a single server. SAP HANA on VMware vSphere® 5.5 is generally available for single virtual machine (VM) running on a dedicated SAP HANA certified server for production use.

![Figure 8: SAP HANA consolidation and flexible deployment](image)

SAP also supports the scenario of running multiple virtual machines on SAP HANA certified servers (for production and non-production use) in controlled availability.

Deploying fully isolated and secure SAP HANA virtual machines is vastly different from SAP Multi-SID installations. As with RAM and CPU resources, overcommitting storage is not supported for both Appliance and Tailored Data Center Integration delivery models. When consolidating virtual machines using the appliance delivery model, the maximum number of licensed SAP HANA virtual machines which can run on a single VMware host is defined by the certified hardware appliance vendor. For Tailored Data Center Integration delivery models only certified storage can be used, work with your storage vendor to determine the maximum number of SAP HANA virtual machines which can be deployed on your storage infrastructure.

**Deployment Best Practices**

The deployment best practices for SAP HANA on VMware vSphere for the computing environment, networking, and storage are described in the sections below.

**Computing Environment**

When SAP HANA is deployed on the vSphere platform, it enables an optimized, purpose-built virtual machine and computing environment. The first step to creating this type of environment is to carefully examine the BIOS settings, and disable unnecessary processes and peripherals in order to direct the compute resources (CPU, memory, network, and I/O) to SAP HANA.
The computing environment features are described in the sections below:

- vSphere host server BIOS settings
- Virtual machine guest operating system
- Hardware-assisted memory virtualization
- Large (huge) memory pages
- Non-Uniform Memory Access (NUMA)
- Wide virtual machines
- Virtual CPUs
- Hyperthreading
- Memory considerations

**vSphere Host Server BIOS Settings**

Servers with Intel® micro-architecture (Nehalem class) including the Intel® Xeon® 5500 series and later CPUs, offers two other power management options: C-states and Intel Turbo Boost. Leaving C-states enabled can increase memory latency. This option is therefore not recommended for low-latency workloads.

### vSphere Host Server BIOS Settings

<table>
<thead>
<tr>
<th>ENABLE THESE SETTINGS</th>
<th>DISABLE THESE SETTINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Virtualization technology (VT)</td>
<td>• Node interleaving</td>
</tr>
<tr>
<td>• Turbo mode</td>
<td>• C1E Halt state</td>
</tr>
<tr>
<td>• Hardware based virtualization support</td>
<td>• Power Management: Set to High Performance</td>
</tr>
<tr>
<td>• Hyperthreading</td>
<td>• Unused features: Video BIOS Shadowable, Video RAM Cacheable, on-board audio, on-board modem, on-board serial ports, on-board parallel ports, on-board game port, floppy drive, CD-ROM, USB</td>
</tr>
<tr>
<td>• Execute Disable (required for vMotion and DRS)</td>
<td></td>
</tr>
</tbody>
</table>

### Table 3: vSphere host server BIOS settings

**Virtual Machine Guest Operating System**

SAP HANA is supported on SUSE® Linux Enterprise Server (SLES) 11 Service Pack 2 or later. Plan the operating system installation to ensure that it takes advantage of VMware virtualization and creates an optimized computing environment.

It is important to ensure that the peripheral components are not re-enabled during operating system installation. Simply disabling the peripheral components in the BIOS does not guarantee that these components are fully disabled.

After the installation, disable unnecessary foreground and background processes. For example, SUSE Linux processes include:

- anacron, apmd, atd, autos, cups, cupsconfig, gpm, isdn, iptables, kudzu, netfs, and portmap

Then install the additional SUSE Linux components on SAP HANA, as described in the table below.

### SUSE Linux Components for SAP HANA

<table>
<thead>
<tr>
<th>SUSE LINUX COMPONENTS</th>
<th>FOR INSTALLATION ON SAP HANA</th>
</tr>
</thead>
<tbody>
<tr>
<td>gtk2</td>
<td>Use the version provided with the operating system distribution.</td>
</tr>
<tr>
<td>java-1_6_0-ibm</td>
<td>Use the version provided with operating system distribution. This is necessary for the SAP HANA Studio on the SAP HANA system.</td>
</tr>
<tr>
<td>libicu</td>
<td>Use the version provided with operating system distribution.</td>
</tr>
<tr>
<td>mozilla-xulrunner192-1.9.2.xx-x.x.x</td>
<td>Use the version provided with the operating system, but at given minimum version.</td>
</tr>
<tr>
<td>ntp, sudo</td>
<td>Use the version provided with operating system distribution.</td>
</tr>
<tr>
<td>syslog-ng</td>
<td>Use the version provided with operating system distribution.</td>
</tr>
<tr>
<td>tcsh, libssh2-1, expect, autoyast2-installation, yast2-ncurses, libgcc, libstdc++</td>
<td>Use the version provided with operating system distribution.</td>
</tr>
</tbody>
</table>

### Table 4: SUSE Linux components for SAP HANA
Observe the following requirement:

- Turn off the SLES kernel dump function (kdump) if it is not needed for specific reasons (for example, a root cause analysis)

Configure the SLES kernel parameter as described below:

- `net.ipv4.tcp_slow_start_after_idle=0`

Adhere to the shared memory settings (if they are not already set during installation), as described in the table below.

<table>
<thead>
<tr>
<th>SIZE</th>
<th>SHMMNI VALUE</th>
<th>PHYSICAL MEMORY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>4096</td>
<td>≥ 24 GB and &lt; 64 GB</td>
</tr>
<tr>
<td>Medium</td>
<td>65536</td>
<td>&gt; 64 GB and &lt; 256 GB</td>
</tr>
<tr>
<td>Large</td>
<td>53488</td>
<td>&gt; 256</td>
</tr>
</tbody>
</table>

Table 5: Shared memory settings for guest operating system

Once the installation is completed, create a SAP HANA “gold” template or clone for consistency, as described above in the “SAP HANA Clones and Template” section earlier in this paper.

For the complete and most current installation instructions always, go to the SAP HANA Server Installation Guide. These setting are highlighted with respect to configuring a Gold copy of SAP HANA on vSphere.

For more information, see the “SAP HANA Server Installation Guide” at: https://help.sap.com/hana/SAP_HANA_Installation_Guide_en.pdf

**Hardware-Assisted Memory Virtualization**

Some recent processors include a feature that addresses overhead due to memory management unit (MMU) virtualization by providing hardware support to virtualize the MMU. Without hardware-assisted MMU virtualization, VMware ESX maintains shadow page tables that directly map guest virtual memory to host physical memory addresses.

These shadow page tables are maintained for use by the processor and are kept consistent with the guest page tables. This allows ordinary memory references to execute without additional overhead, since the hardware translation lookaside buffer (TLB) caches direct guest virtual memory to host physical memory address translations that are read from shadow page tables. However, extra work is required to maintain the shadow page tables.

Hardware assistance eliminates software memory virtualization overhead. In particular, it eliminates the overhead required to keep the shadow page tables in synchronization with the guest page tables, although the TLB miss latency is significantly higher. This means, hardware assistance provides workload benefits depending primarily on the memory virtualization overhead that is caused when using software memory virtualization.

If a workload involves a small amount of page table activity, such as process creation, mapping the memory, or context switches, software virtualization does not cause significant overhead. However, workloads having a large amount of page table activity, such as workloads from a database, are likely to benefit from hardware assistance.

For these reasons, enabling vSphere to Choose the Best Virtual Machine Monitor based on the CPU and guest operating system combination is recommended.

**Large (Huge) Memory Pages**

SAP HANA is supported only on the standard SLES 11 or SLES 11 for SAP applications guest operating systems. The same operating system requirements for SAP HANA hardware appliances also apply to SAP HANA virtual machines. Starting with SLES 11 SP2, Linux can use transparent HugePages to enable the use of large pages with SAP HANA.

Large (huge) pages can potentially increase TLB access efficiency, thereby improving database performance. The use of large pages can significantly improve the performance of SAP HANA databases on vSphere, as compared to running the workload using small pages.
Using transparent HugePages enabled at the operating system level, typically achieves approximately a 10 percent performance improvement. Enabling HugePages is the default behavior and it is enabled by default on SLES 11 SP2 and later.

**Non-Uniform Memory Access (NUMA)**

The Non-Uniform Memory Access (NUMA) architecture is common on servers with multiple processor sockets. It is important to understand this memory access architecture when sizing memory-bound and latency-sensitive systems.

A NUMA node is equivalent to one CPU socket. For a server with two sockets, there are two NUMA nodes. Therefore, the available number of physical CPU cores and RAM can be divided equally among NUMA nodes. This is critical when sizing virtual machines to fit within one NUMA node. For example, a 4-socket, 40-core (10 cores on each socket) server with 512 GB RAM, has four NUMA nodes, each with 10 physical cores (CPUs) and 128 GB RAM (512 divided by 4).

When sizing virtual machines, it is important to carefully consider NUMA node boundaries. For this example, if there are 10 vCPUs and 128 GB RAM, Exceeding the CPU and RAM size boundaries of a NUMA node causes the virtual machine to fetch memory from a remote location, and this can diminish performance.

**Wide Virtual Machines**

In cases where the CPU or RAM of a single NUMA node does not provide enough resources for a given workload, it is recommended to use a virtual machine that is larger than a single NUMA node. In this instance, performance becomes better, despite remote memory access, since the need for additional CPU or RAM has a larger effect on performance.
In general, size virtual machines to fit within as few NUMA nodes as possible, and do not oversize the virtual machine. This could cause unnecessary remote memory accesses. In addition, the vSphere ESXi CPU Scheduler is NUMA-aware and it has been designed to avoid remote memory accesses to the extent possible.

If the virtual machine appears to have poor NUMA locality, inspect the N%L counter from esxtop. With good NUMA locality, it is 100 percent. For more information, see “Appendix A: Troubleshooting vSphere Related Issues” later in this paper.

**Virtual CPUs (vCPUs)**

When configuring SAP HANA virtual machines for production environments, ensure that the total vCPU resources for the virtual machines running on the system do not exceed the CPU capacity of the host. Do not over-commit CPU resources on the host. If the host CPU capacity is overloaded, the performance of the virtual database might degrade.

Configuring virtual SAP HANA with excess vCPUs can impose a small resource requirement on vSphere because unused vCPUs continue to consume timer interrupts. vSphere co-schedules virtual machine vCPUs and attempts to run the vCPUs in parallel to the best extent possible. Unused vCPUs impose scheduling constraints on the vCPU being used and can degrade its overall performance.

**Hyperthreading**

Hyperthreading for processors allows for multiple instruction threads to execute on a single physical core. While many of the core’s resources are actually shared between cores, the additional logical thread allows for an increase in performance, usually in the range of 10 to 20 percent. It is recommended to enable hyperthreading on any system running vSphere and SAP HANA.

Virtual CPUs that are assigned to a vSphere virtual machine are mapped to a logical thread on the physical server on which they are running. When hyperthreading is enabled, each physical core has two logical threads. In order to assign all of the CPU resources to virtual machines, the number of virtual CPUs assigned needs to equal the number of logical threads on the server. For example, an Intel® Xeon® Processor E7 Series (Westmere-EX) based server that has 10 cores per socket and four sockets has a total of 40 physical cores and 80 logical threads.

For more information that describes how to size and configure HANA-based virtual machines for vCPUs, physical cores, and hyperthreading, see the “Virtual SAP HANA Sizing” section later in this paper.

**Memory Considerations**

For memory, the best practice is to configure memory reservations equal to the size of the SAP HANA configured RAM. Do not over commit memory. When consolidating multiple non-production SAP HANA instances on the same host, vSphere can share memory across all of the virtual machines that are running the same operating system. In this case, vSphere uses a proprietary, transparent page-sharing technique to reclaim memory. This allows databases to run with less memory than when physical RAM is used.

In this case, leave memory for overhead of the vSphere ESXi kernel and for the virtual machines. As a conservative estimate, it would be safe to use up to 5 percent of system memory for this overhead. Do not assign memory overhead to virtual machines.


**Networking**

For SAP HANA, the networking configuration includes Virtual Distributed Switch (vDS) and VMXNET 3 optimization. Each is described in the sections below.

**Virtual Distributed Switch (vDS)**

SAP HANA uses Virtual Distributed Switches. Prior to vSphere 4.0, virtual infrastructure administrators configured standard switches on each host. vDS enables virtual machine networking that spans multiple vSphere hosts to be managed as a single virtual switch from a centralized VMware vCenter Server through vSphere Client.
When a vSphere host is added, the networking for that host does not require configuration. Instead, the host is added to a defined port group that is dedicated to SAP HANA traffic or other application-specific traffic.

In addition to supporting Private VLANs (PVLANs), vDS can also be used to shape both inbound and outbound network traffic. VMware Standard Switches can be easily migrated to vDS in a non-disruptive manner with the vCenter Server management user interface.

**VMXNET 3**

The best practice is to use VMXNET 3 virtual NICs for SAP HANA virtual machines. VMXNET 3 is the latest generation of paravirtualized NICs that are designed from the ground-up for performance and latency-sensitive workloads.

VMXNET3 offers several advanced features including multi-queue support, Receive Side Scaling, IPv4/IPv6 offloads, and MSI/MSI-X interrupt delivery.

By default, VMXNET 3 also supports an adaptive interrupt coalescing algorithm for the same reason that physical NICs implement interrupt coalescing. Virtual interrupt coalescing helps drive high throughput to the virtual machines with multiple vCPUs with parallelized workloads.

Red Hat Enterprise Linux 6 and SUSE Linux Enterprise Server 11 SP1 ship with built-in support for VMXNET 3 NICs. In this case, VMware Tools is not required to enable the VMXNET 3 driver configuration for these guest operating systems.

**Storage**

For SAP HANA deployments, a typical storage configuration includes Virtual Machine File System (VMFS), datastores, and Paravirtualized SCSI adapters.

The storage features are described in the sections below:

- Virtual Machine File System (VMFS)
- Datastores
- Paravirtual SCSI adapters
- Multiple virtual SCSI controllers
- File system considerations and alignment
- SUSE Linux I/O Scheduler

**Virtual Machine File System**

VMware vSphere VMFS provides high performance, clustered storage virtualization that is optimized for virtual machines. With VMFS, each virtual machine is encapsulated into a small set of files. VMFS is the default storage management interface that is used to access those files on physical SCSI disks and partitions. VMFS allows multiple ESX instances to access shared virtual machine storage concurrently. It also enables virtualization-distributed infrastructure services, such as VMware vMotion, DRS, and High Availability, to operate across a cluster of ESX hosts.

In order to balance performance and manageability in a virtual environment, it is an accepted best practice to deploy databases using VMFS. Raw Device Mapping (RDM) is sometimes erroneously selected to provide increased performance. The two dominant workloads associated with databases, random read/write and sequential writes, have nearly identical performance throughput characteristics when deployed on VMFS or using RDM.

**SAP HANA TDI and IBM General Parallel File System**

The IBM General Parallel File System (GPFS) is an excellent, high performance shared disk management solution and a key component of the IBM SAP HANA framework that enables the sharing of local disk resources.

Because TDI allows customers to use their existing shared enterprise storage environments, GPFS is not recommended for the virtualization of SAP landscapes when using VMware vSphere. The features below are not supported with GPFS:

- VMware vMotion, Distributed Resource Scheduler (DRS), Fault Tolerance (FT), cloning
- N_Port ID virtualization (NPIV)
- IBM GPFS running on mixed VMware ESXi versions
- Use of Persistent Reservations (not supported with VMware)

In addition, with GPFS, pass-through only is supported with Raw Device Mapping (RDM) using the physical compatibility model.

**Datastores**

vSphere uses datastores to store virtual disks. Datastores provide an abstraction of the storage layer that hides the physical attributes of the storage devices from the virtual machines. VMware administrators can create datastores that can be used as a single consolidated pool of storage, or many datastores that can be used to isolate various application workloads.

In traditional Storage Area Network (SAN) deployments, it is an accepted best practice to create a dedicated datastore if the application has a demanding I/O profile. Databases fall into this category. The creation of dedicated datastores with vSphere allows database administrators to define individual service level agreements (SLAs) for different applications. This is analogous to provisioning dedicated logical units (LUNs) in the physical world.

In summary, with SAP HANA on vSphere, datastores can be used as follows:
- Create separate and isolated datastores for SAP HANA data and logs.
- Multiple SAP HANA virtual machines can have their data and log virtual machine disk files provisioned on the same class of storage.
- Provision virtual machine disk files as eager zeroed thick to avoid lazy zeroing.

**Paravirtual SCSI Adapters**

It is a best practice to create a primary adapter for use with a disk that hosts the system software and SAP HANA binaries, and to separate paravirtual SCSI (PVSCSI) adapters for the SAP HANA data and log devices. PVSCSI adapters are high performance storage adapters that can result in greater throughput and lower CPU utilization.

To configure PVSCSI adapters for use with the SAP HANA, see the VMware Knowledge Base article “Configuring disks to use VMware Paravirtual SCSI (PVSCSI) adapters (1010398)” at: http://kb.vmware.com/selfservice/microsites/search.do?cmd=displayKC&docType=kc&externalId=1010398&sliceId=1&docTypeID=DT_KB_1_1&dialogID=124929562&stateId=00124933974.

**Multiple Virtual SCSI Controllers**

VMware recommends creating multiple virtual SCSI controllers to distribute the I/O associated with database workloads. When creating multiple SCSI controllers, map these controllers to the database or operating system workload profile. Ensure that the operating system and SAP HANA binaries reside on one SCSI controller, and the SAP HANA data files and log files reside on separate SCSI controllers.

The primary purpose for using multiple virtual SCSI controllers is to parallelize the units of work in a database transaction or query. In this case, carefully consider the implications when using multiple SCSI controllers to parallelize a single unit of work within a transaction. For instance, creating several SCSI controllers for data files increases throughput, but it may also increase latency.

<table>
<thead>
<tr>
<th>VIRTUAL SCSI DRIVER</th>
<th>VIRTUAL DEVICE</th>
<th>DESCRIPTION</th>
<th>RECOMMENDED SIZE</th>
<th>VIRTUAL POOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSI Logic</td>
<td>0:0</td>
<td>/usr/sap</td>
<td>50 GB</td>
<td>RAID 5</td>
</tr>
<tr>
<td>Paravirtual</td>
<td>1:0</td>
<td>/hana/data/&lt;SID&gt;</td>
<td>3x memory</td>
<td>RAID 5</td>
</tr>
<tr>
<td>Paravirtual</td>
<td>2:0</td>
<td>/hana/log/&lt;SID&gt;</td>
<td>1x memory</td>
<td>RAID 1</td>
</tr>
<tr>
<td>Paravirtual</td>
<td>3:0</td>
<td>/hana/shared/&lt;SID&gt;</td>
<td>N/A</td>
<td>RAID 5</td>
</tr>
</tbody>
</table>

Table 6: SAP HANA layout for virtual SCSI controllers
File System Considerations and Alignment
As in the physical world, file system misalignment can severely impact performance. File system misalignment not only manifests itself in databases, but with any high I/O workload. VMware makes these recommendations for VMware VMFS partitions:

• Similar to other disk-based file systems, VMFS suffers a penalty when the partition is not aligned. Use VMware vCenter to create VMFS partitions, since it automatically aligns the partitions along the 64 KB boundary.
• In order to manually align your VMware VMFS partitions, check your storage vendor’s recommendations for the partition starting block (for example, EMC VNX uses 128K offsets).

SUSE Linux I/O Scheduler
As of the Linux 2.6 kernel, the default I/O Scheduler is Completely Fair Queuing (CFQ). The scheduler is an effective solution for nearly all workloads. The default scheduler affects all disk I/O for VMDK-based and RDM-based virtual storage solutions. In virtualized environments, it is often not beneficial to schedule I/O at both the host and guest layers. If multiple guests use storage on a file system or on a block device managed by the host operating system, the host might be able to schedule I/O more efficiently, since it recognizes requests from all guests and the physical layout of storage, which might not map linearly to the guests’ virtual storage.

Testing shows that NOOP performs better with virtualized Linux guests. ESXi uses an asynchronous intelligent I/O scheduler. For this reason, virtual guests obtain improved performance by allowing ESXi to handle I/O scheduling.

For additional information, see “Linux 2.6 kernel-based virtual machines experience slow disk I/O performance (2011861)” at: http://kb.vmware.com/kb/2011861.

Optimizing SAP HANA on vSphere
In general, the testing and performance characterization of SAP HANA on the VMware vSuite was conducted using the following VMware ESXi performance tunings. This section describes the additional optimizations that are tailored specifically for running SAP HANA in a VMware virtualization environment.

VMware vSphere can run multiple virtual machines in a heterogeneous clustered environment. In order to create SAP landscapes, application owners and VI admins need to weigh the advantages of absolute performance versus heterogeneity.

These additional optimizations are described in the sections below:

• Workload optimization
• Pinning virtual NUMA to physical NUMA
• NIC optimization
• Virtual SCSI adapter optimization

Workload Optimization
In order to achieve optimal performance for a productive SAP HANA virtual machine, use the settings described in the sections below. In terms of CPU scheduling and priority, these settings improve performance by reducing the amount of vCPU and vNUMA migration, while increasing the priority of the SAP HANA production virtual machine.
Pinning Virtual NUMA to Physical NUMA

vCPU pinning may be used to keep the virtual NUMA nodes from migrating to different physical NUMA nodes. Pin each vCPU to a physical NUMA node using the pattern of configuration settings in the virtual machine’s .vmx file, or via the Advanced Configuration parameters section in the vSphere client.

Notice the example below:

```plaintext
sched.vcpu0.affinity = "0-19"
...
sched.vcpu9.affinity = "0-19"
sched.vcpu10.affinity = "20-39"
....
sched.vcpu19.affinity = "20-39"
sched.vcpu20.affinity = "40-59"
....
sched.vcpu29.affinity = "40-59"
sched.vcpu30.affinity = "60-79"
....
sched.vcpu39.affinity = "60-79"
```

Low Latency Setting

In order to achieve the absolute lowest possible latency for SAP HANA, it recommended to set the latency sensitivity setting to high as follows:

Go to the settings for the SAP HANA virtual machine. Click the Virtual Machine Options tab, select Advanced, and then select High for the Latency Sensitivity setting.

To further improve performance and reduce latency, set the memory for the virtual machine to be preallocated:

Go to Virtual Machine Settings in vCenter Server for the SAP HANA virtual machine, click the Virtual Machine Options tab, select Advanced, and then select Configuration Parameters. Add two new rows as shown below:

```plaintext
sched.mem.prealloc = "TRUE"
sched.swap.vmxSwapEnabled = "FALSE"
```

NIC Optimization

Most network interface cards (NICs) provide a mechanism to disable interrupt coalescing that is usually available via the ethtool command and/or module parameters.

In order to determine if disabling the physical NIC interrupt moderation on the VMware ESXi host is needed, enter the command below:

- `# esxcli system module parameters set -m ixgbe -p "InterruptThrottleRate=0"`

This example applies to the Intel® 10 GbE driver, called ixgbe. In order to find the appropriate module parameter for the NIC, first find the driver using the ESXi command below:

- `# esxcli network nic list`

Then find the list of module parameters for the driver being used:

- `# esxcli system module parameters list -m <driver>`
Large Receive Offload (LRO) is another feature of VMXNET 3 that helps deliver high throughput with lower CPU utilization. LRO aggregates multiple received TCP segments into a larger TCP segment before delivering it to the guest TCP stack.

However, for latency-sensitive applications that rely on TCP, the time spent aggregating smaller TCP segments into a larger one adds to the latency. It can affect TCP algorithms such as TCP delayed acknowledgment (ACK) that causes the TCP stack to delay an ACK until the two larger TCP segments are received. This also adds to the end-to-end latency of the application.

In order to determine if disabling LRO benefits application stack requirements, reload the VMXNET 3 driver in the Linux guest operating system:

```
# modprobe -r vmxnet3
```

Add the following line in `/etc/modprobe.conf` (Linux-version dependent):

```
options vmxnet3 disable_lro=1
```

Then reload the driver using:

```
# modprobe vmxnet3
```

**Virtual SCSI Adapter Optimization**

In order to increase the queue depth of the pvSCSI driver inside the Linux-based guest on which SAP HANA runs, add the Linux kernel boot options below:

```
vmw_pvscsi.cmd_per_lun=1024
vmw_pvscsi.ring_pages=32
```

**Deployment Tips and Guidelines**

A summary of tips and guidelines for deploying SAP HANA on VMware vSphere are described in the table below.

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>SETTINGs</th>
</tr>
</thead>
</table>
| SUSE operating system | • XFS file system  
                        | • NOOP I/O Scheduler  
                        | • Hyperthreading enabled  
                        | • pvSCSI kernel parameters added  
                        |  - vmw_pvscsi.cmd_per_lun=1024  
                        |  - vmw_pvscsi.ring_pages=32    |
| Virtual machine BIOS | • Enable:  
                        |  - Virtualization Technology (VT)  
                        |  - Turbo mode  
                        |  - Hardware based virtualization support  
                        |  - Hyperthreading  
                        |  - Execute Disable (required for vMotion/DRS)  
                        | • Disable:  
                        |  - Node interleaving  
                        |  - CIE Halt state  
                        |  - Power management – High performance  
                        | • Unused features: Video BIOS Shadowable, Video RAM Cacheable, on-board audio, on-board modem, on-board serial ports, on-board parallel ports, on-board game port, floppy drive, CD-ROM, USB |
Best Practices and Recommendations for Scale-up Deployments of SAP HANA on VMware vSphere

**COMPONENT**

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>SETTINGS</th>
</tr>
</thead>
</table>
| SAP HANA virtual machine | • Use Virtual Hardware version 10 or higher.  
  • Use large (huge) pages.  
  • Do not overcommit CPU or memory resources.  
  • Use as few NUMA nodes as possible.  
  • Do not oversize the virtual machine.  
  • Use VMXNET 3 virtual NICs.  
  • Use paravirtualized SCSI driver for I/O devices.  
  • Set Latency Sensitivity to High for the virtual machine.  
  • Use LSI Logic SCSI driver for operating system SAP HANA binaries.  
  • Align file system offset. For example: VNX 128K offset.  
  • Use Virtual Machine Disk (VMDK) file system.  
  • Create dedicated and isolated datastores for SAP HANA data and log files.  
  • Use eager zeroes thick virtual disks to avoid lazy zeroing.  
  • Use multiple virtual SCSI controllers.  
  • Post installation, create SAP HANA “Gold” clone or template.  
  • Set the memory for the virtual machine to be preallocated. |
| vSphere 5.5 host | • Allow vSphere to “Choose the Best Virtual Machine Monitor” based on the CPU and guest operating system combination.  
  • Hardware Assisted Memory Virtualization - CPU/MMU Virtualization Option = Automatic  
  • Use Virtual Distributed Switch (VDS) for ease of management and to isolate database, application, and vMotion traffic on separate VLANS. |

**Virtual SAP HANA Sizing**

Sizing SAP HANA for a virtual environment is the same as sizing SAP HANA for a native environment, except for a few differences. These differences are due to the size limitations of virtual machines, virtual CPU to physical CPU mappings, and the slight overhead cost of virtualization. The basic process is to size the SAP HANA database normally (the same sizing that is done for native SAP HANA), and then make any needed adjustments to account for virtualization.

Each of these factors that are used for sizing virtual SAP HANA correctly are described in detail with examples in the sections below. These factors include:

• Maximum virtual machine size  
• Virtual CPU to physical CPU mapping  
• Memory overhead  
• SAP HANA sizing approaches  
• SAP-based SAP HANA sizing  
• SAP HANA T-shirt sizing  
• Sizing for maximum virtual machine performance  
• Sizing for maximum total system performance  
• Sizing example for multiple SAP HANA virtual machines on a single vSphere ESXi host

Each of these factors is described in the sections below.
Maximum Virtual Machine Size
The maximum virtual machine size in vSphere 5.5 is 64 vCPUs and 1 TB of RAM. This is smaller than the 4-socket and 8-socket servers that are used for SAP HANA hardware appliances. It is not possible to directly map these larger sized SAP HANA hardware appliances to a virtual machine.

Virtual CPU to Physical CPU Mapping
The current generation of Intel processors that are used for SAP HANA have a feature called hyperthreading. Hyperthreading allows each physical core to have two execution threads. These threads share the resources of the same physical core. This means, they do not double performance, but instead provide a 10 to 20 percent increase in performance, in most cases.

A vCPU that is created for a virtual machine is scheduled to run on a logical thread. A vCPU maps directly to a logical thread on a physical core.

The default behavior for vSphere is to schedule vCPUs on separate physical CPUs, using a single execution thread on each physical core first. Once all of the physical cores have a vCPU scheduled and running, then vSphere can begin to schedule vCPUs to use the second logical execution thread on each physical core.

From a sizing perspective, vCPUs are equivalent to physical cores without hyperthreading enabled, in terms of performance. In order to obtain up to an additional 10 to 20 percent of performance with hyperthreading enabled, the number of vCPUs needs to be doubled. In other words, a physical SAP HANA server system with 64 physical cores, and with hyperthreading enabled, would provide 10 to 20 percent higher performance than a virtual SAP HANA server system (virtual machine) with 64 vCPUs and 64 execution threads, all mapped to physical cores of the example server.

Memory Overhead
Virtual machines have full access and use of the amount of RAM that is assigned to the virtual machine when it is created. However, some memory is needed to run the ESXi hypervisor and manage the virtual memory assigned to the virtual machines. Many vSphere customers never notice this memory overhead due to the many memory optimization techniques that have been implemented.

Production SAP HANA virtual machines have full memory reservation. This feature does not allow for memory optimization techniques to be enabled. For this reason, it is necessary to leave a small amount of unassigned RAM on the host to account for the memory needed by the hypervisor and virtual machine memory overhead.

A very conservative estimate for the amount of RAM that needs to be unassigned the SAP HANA virtual machines for overhead is 3 to 4 percent. For example, on a system having 1 TB of RAM, approximately 30 to 40 GB would need to be left unassigned to the virtual machines. A single large virtual machine with 980 GB, or two virtual machines with 490 GB each, could be created and leave enough unassigned memory for the hypervisor and virtual machine memory overhead.

Note that this memory overhead is visible to the memory reservations configured for SAP HANA virtual machines. In an environment where resource over-commitment is allowed, this memory overhead does not need to be calculated and configured.

SAP HANA Sizing Approaches
The sizing of a virtualized SAP HANA system follows the same method as the sizing of a native SAP HANA system. In this case, an initial system sizing is completed using the SAP QuickSizer or a sizing is based on an existing system. The results of these efforts is a number that represents the needed performance for the system that is to run the application that was sized. This number, called SAPS, represents a unit of performance.

SAP partners use provided benchmarks to test their systems to measure their capability in terms of SAPS. Beside SAPS sizing, a memory sizing also needs to be performed. Once the needed compressed memory size is determined, the memory of a SAP HANA virtual machine can be defined.

In addition, SAP applications sizing is done in terms of SAPS. SAP HANA hardware appliances have been sized with T Shirt sizing (S,M,L) to make the configuration and selection easy for customers, and this sizing is available from hardware vendors. A combination of these two methods are used with SAP HANA. Both methods are described in the following sections of this paper.
SAP-based SAP HANA Sizing

SAPS or SAP Application Performance Standard is a hardware-independent value that describes the performance of a system configuration in a SAP environment. SAPS is derived from the Sales and Distribution (SD) benchmark, where 100 SAPS is defined as 2,000 fully business-processed order line items per hour.

Using SAPS, the CPU resource requirements for a SAP HANA system can be calculated. Since SAP HANA is an in-memory platform, the memory needs of a SAP HANA system are calculated based on capacity sizing. Typically, this sizing is determined by the customer working in conjunction with SAP or partners. The tools and resources used for this effort are the same for both virtual and native environments. Once these initial sizing numbers are determined, they can be used to define the size of the virtualized SAP HANA virtual machine and the size of the vSphere host.

For more information about sizing, see the “SAP Service Marketplace” at: https://service.sap.com/sizing. (Note that accessing this site requires your standard SAP support portal credentials.)

The performance of CPUs continues to improve with each new release. The SAPS rating for a virtual machine depends on the performance of the physical cores on which it is running. For SAP HANA, the Intel® Xeon® Processor E7 Series (Westmere-EX) and Intel® Xeon® Processor E7 v2 Series (Ivy Bridge-EX) are currently supported. This means that the SAPS rating for a given virtual machine might be different, depending on the processor on which it runs.

Since no official published benchmark results for SAP applications running on vSphere exists with Intel E7 CPUs, averages of official published SAPS per core figures of the SAP-certified Westmere-EX and Ivy Bridge-EX CPUs are used, as summarized in tables below.

These tables also show the average virtualized SAPS figure for each Intel Xeon Processor E7 core. In this case, it is reduced by 10 percent for virtualization overhead, and with a potential hyperthreading performance gain of 20 percent, when running a server with all of the available execution threads for a single application or database.

Based on these two assumptions, the following formula can be used to calculate the average virtualized SAPS/core without hyperthreading:

\[
\text{Virtualized SAPS} = \frac{\text{Native SAPS}}{1.1 \text{ (overhead)}} \times \frac{1}{1.2 \text{ (Hyperthreading)}}
\]

Note: The information in the tables below are average figures. A specific hardware vendor may use higher or lower rated figures for their specific SAP HANA system.

Table 8 shows the available average SAPS sizing figures per CPU core of a Westmere-EX CPU.

<table>
<thead>
<tr>
<th>CPU</th>
<th>Average Native SAPS/Core with Hyperthreading</th>
<th>Average Virtualized SAPS/Core without Hyperthreading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel Xeon Processor E7 2870</td>
<td>1745</td>
<td>1320</td>
</tr>
<tr>
<td>Intel Xeon Processor E7 4870</td>
<td>1730</td>
<td>1310</td>
</tr>
<tr>
<td>Intel Xeon Processor E7 8870</td>
<td>1670</td>
<td>1260</td>
</tr>
</tbody>
</table>

Table 8: Intel Westmere-EX CPU core SAPS figures

Table 9 shows the available average SAPS sizing figures per CPU core of a Ivy Bridge-EX CPU.

<table>
<thead>
<tr>
<th>CPU</th>
<th>Average Native SAPS/Core with Hyperthreading</th>
<th>Average Virtualized SAPS/Core without Hyperthreading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel Xeon Processor E7 v2 4890</td>
<td>2230</td>
<td>1680</td>
</tr>
</tbody>
</table>

Table 9: Intel Ivy Bridge-EX CPU core SAPS figures
For details about Public available SAP Standard Application Benchmark results, see the following website at: http://www.sap.com/benchmark.

The SAP HANA system must also be sized for memory. For more information, see the published sizing guidelines for SAP BWoH and SoH at:


**Note:** Memory sizing is required to define the correct virtual memory size of a SAP HANA virtual machine.

As mentioned above, it is important to note that a vCPU is not exactly equivalent to a full physical core because it is mapped to a logical execution thread. When hyperthreading is enabled, a physical core has two execution threads. This means, two vCPUs are needed in order to use both execution threads. However, the additional thread created by enabling hyperthreading does not double the performance of the core. Enabling hyperthreading usually increases overall system performance by approximately 10 to 20 percent.

The default behavior for vSphere is to schedule vCPUs on separate physical cores, essentially giving each vCPU its own core. Once all physical cores have been used, vSphere then starts scheduling vCPUs on the second logical thread of the physical cores.

Besides the custom SAPS sizing, hardware vendors also provide pre-configured SAP HANA appliance systems.

### SAP HANA T-Shirt Sizing

SAP HANA hardware-based appliances are available in different pre-configured sizes, called SAP HANA T-Shirt sizes. VMware vSphere 5.5 supports up to a maximum of 64 vCPUs and 1 TB of RAM per virtual machine. SAP HANA hardware appliances sizes are based on the Westmere-EX or Ivy Bridge-EX CPUs, which has 10 or up to 15 cores per processor.

The SAP HANA T-Shirt configurations that are available follow a set CPU-to-memory ratio that varies depending on whether SAP BW on HANA (BWoH) or SAP Business Suite on HANA (SoH) is being used and which CPU type is used.

The tables below show some example virtualized SAP HANA T-Shirt sizes, by maintaining the same CPU to-memory ratio used by the hardware appliances. As an extension of the previous section “SAP-based SAP HANA Sizing”, these tables also shows the calculated SAPS for each configuration.

As discussed above, a small amount of memory is needed for virtualization and it must be accounted for on the server. If all of the installed physical memory is to be assigned to SAP HANA virtual machines, then the memory assigned to the SAP HANA virtual machines needs to be reduced by 3 to 4 percent. For example, a system with 1 TB (1024 GB) of RAM that is to host two SAP HANA virtual machines, would need each virtual machine to be sized with 490 GB each, instead of 512 GB each, to allow the hypervisor memory for operation.

**Note:** Before using T-Shirt sized SAP HANA virtual machines, a custom SAPS and RAM sizing is preferred. It should be performed to meet the real SAP application and SAP HANA resource requirements. When the SAPS and RAM requirement for a custom SAP application on SAP HANA is defined, the core-to-memory ratio may be different than the T-Shirt sized SAP HANA virtual machines. Configurations in compliance with the SAP HANA sizing documentation are fully supported configurations.
The table below uses the same T-shirt sizing that is used in hardware and it maintains the same memory-to-CPU ratio for virtual SAP HANA T-Shirt sizing of the Westmere-EX based hardware platform for SAP BW powered by SAP HANA (BWoH). The RAM of these examples was chosen to ensure NUMA node memory locality, which provides best memory performance and have to get adopted the to the actual total available RAM installed in the server.

<table>
<thead>
<tr>
<th>SOCKETS (CPU)</th>
<th>vCPU (CORES)</th>
<th>TOTAL vCPUs</th>
<th>RAM IN GB</th>
<th>SAPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>5</td>
<td>64</td>
<td>6560</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>10</td>
<td>128</td>
<td>13120</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>20</td>
<td>256</td>
<td>26240</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>40</td>
<td>512</td>
<td>52480</td>
</tr>
</tbody>
</table>

Table 10: Virtualized BWoH example sizings – Westmere-EX (2.4 GHz)

The table below uses the same T-shirt sizing that is used in hardware and it maintains the same memory-to-CPU ratio for virtual SAP HANA T-Shirt sizing of the Ivy Bridge-EX based hardware platform for SAP BW powered by SAP HANA (BWoH).

<table>
<thead>
<tr>
<th>SOCKETS (CPU)</th>
<th>vCPU (CORES)</th>
<th>TOTAL vCPUs</th>
<th>RAM IN GB</th>
<th>SAPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>5</td>
<td>64</td>
<td>8440</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>10</td>
<td>128</td>
<td>16890</td>
</tr>
<tr>
<td>1</td>
<td>15</td>
<td>15</td>
<td>128</td>
<td>25340</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>30</td>
<td>256</td>
<td>50680</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>45</td>
<td>768</td>
<td>76020</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>60</td>
<td>1024</td>
<td>101360</td>
</tr>
</tbody>
</table>

Table 11: Virtualized BWoH example sizings – Ivy-Bridge (2.8 GHz)

The table below uses the same T-shirt sizing that is used in hardware and it maintains the same memory-to-CPU ratio for virtual SAP HANA T-Shirt sizing of the Westmere-EX based hardware platform for SAP Business Suite powered by SAP HANA (SoH). The RAM of these examples was chosen to ensure NUMA node memory locality, which provides best memory performance and have to get adopted the to the actual total available RAM installed in the server.

<table>
<thead>
<tr>
<th>SOCKETS (CPU)</th>
<th>vCPU (CORES)</th>
<th>TOTAL vCPUs</th>
<th>RAM IN GB</th>
<th>SAPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>5</td>
<td>64</td>
<td>6560</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>5</td>
<td>128</td>
<td>6560</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>10</td>
<td>256</td>
<td>13120</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>20</td>
<td>512</td>
<td>26240</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>30</td>
<td>768</td>
<td>39360</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>40</td>
<td>1024</td>
<td>52480</td>
</tr>
</tbody>
</table>

Table 12: Virtualized SoH example sizings – Westmere-EX (2.4 GHz)
The table below uses the same T-shirt sizing that is used in hardware and it maintains the same memory-to-CPU ratio for virtual SAP HANA T-Shirt sizing of the Ivy Bridge-EX based hardware platform for SAP Business Suite powered by SAP HANA (SoH).

<table>
<thead>
<tr>
<th>SOCKETS (CPU)</th>
<th>vCPU (CORES)</th>
<th>TOTAL vCPUs</th>
<th>RAM IN GB</th>
<th>SAPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>5</td>
<td>64</td>
<td>8440</td>
</tr>
<tr>
<td>1</td>
<td>15</td>
<td>15</td>
<td>192</td>
<td>25340</td>
</tr>
<tr>
<td>1</td>
<td>15</td>
<td>15</td>
<td>256</td>
<td>25340</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>30</td>
<td>512</td>
<td>50680</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>45</td>
<td>768</td>
<td>76020</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>60</td>
<td>1024</td>
<td>101360</td>
</tr>
</tbody>
</table>

Table 13: Virtualized SoH example sizings – Ivy-Bridge (2.8 GHz)

Note: Provisioning of SAP HANA as a virtual machine is not limited to these specific configurations, although it has to follow the SAP HANA sizing guidelines that are published by SAP.

It is recommended that a SAP HANA virtual machine configuration be no smaller than 5 cores and 64 GB RAM, and scale to 64 vCPUs and 1 TB of RAM. This flexible configuration allows each SAP HANA instance to be sized based on actual need and not as pre-configured SAP HANA appliance systems dictate.

The T-shirt sizing examples above assume that, while hyperthreading is enabled on the server, the virtual machine is being configured to achieve the best performance per vCPU. Each vCPU has its own physical core on which to execute. This means, a one-to-one mapping of vCPUs to physical cores, and if possible, physical CPU sockets to virtual CPU sockets.

In order to maximize the performance of the overall system and use hyperthreading for vCPUs, the number of vCPUs needs to be doubled, while keeping the memory constant.

**Sizing for Maximum Virtual Machine Performance**

In order to achieve the highest possible performance for a single virtual machine, each vCPU requires its own physical core. This means, a 1:1 ratio of vCPUs to pCPUs. For example, suppose there is one large virtual machine with 64 vCPUs, with each vCPU running on its own physical core. In this case, 64 vCPUs is equal to 64 physical CPUs without hyperthreading.

**Sizing for Maximum Total System Performance**

Because newer physical servers have more CPU cores/threads available than the configuration maximum of vCPUs, it is not possible to assign all threads of a server to a single virtual machine. In order to use all logical threads in SAP HANA virtual machines, it is necessary to create multiple virtual machines. For an Intel Westmere-EX CPU with four sockets and 10 cores per socket, the system would have a total of 80 logical threads. For example, a virtual machine configuration that uses all of the threads would require four virtual machines, with each having 20 logical threads, with each virtual machine kept assigned, such that it uses its own 10 physical cores only.

**Sizing Example for Multiple SAP HANA Virtual Machines on a Single vSphere ESXi Host**

One of the use cases for virtualization is the consolidation of SAP HANA. While consolidating multiple SAP HANA virtual machines on a single server, the SAPS capacity and usable memory must not be exceeded. Again SAP also supports the scenario of running multiple virtual machines on SAP HANA certified servers (for production and non-production use) in controlled availability.

The examples below show a consolidation scenario of SAP HANA virtualized instances for production use (table 14) and non-production use (table 15) on a single 4-socket vSphere host. The tables show that the configured resources do not exceed the available resources of the host by ensuring enough resources are left for the vSphere ESXi kernel to operate.
These sizing examples show how easy it is to align the T-Shirt sizing SAP HANA configurations by maintaining the core-to-memory ratio and SAPS capacity of a server.

**Note:** In the examples below more RAM could have got assigned to the SAP HANA VM. The memory the ESXi kernel needs to operate is maximal 3-4% of the total RAM of all running SAP HANA VM instances.

<table>
<thead>
<tr>
<th>PHYSICAL SERVER</th>
<th>CPUs</th>
<th>pCOREs</th>
<th>TOTAL pCOREs</th>
<th>RAM IN GB</th>
<th>SAPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-socket server</td>
<td>4</td>
<td>10</td>
<td>40</td>
<td>1024</td>
<td>69280</td>
</tr>
<tr>
<td>SAP HANA virtual machines (VMs)</td>
<td>Sockets (CPU) vCPU (cores) Total vCPUs</td>
<td>RAM in GB</td>
<td>SAPS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SoH VM 1</td>
<td>2</td>
<td>10</td>
<td>20</td>
<td>512</td>
<td>26240</td>
</tr>
<tr>
<td>BWoH VM 2</td>
<td>2</td>
<td>10</td>
<td>20</td>
<td>256</td>
<td>26240</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>40</td>
<td>768</td>
<td>52480</td>
</tr>
</tbody>
</table>

**Remaining Resources for vSphere ESXi**

<table>
<thead>
<tr>
<th>CPUs</th>
<th>Hyperthreads</th>
<th>Total Hyperthreads</th>
<th>RAM in GB</th>
<th>SAPS*</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESXi Kernel</td>
<td>4</td>
<td>10</td>
<td>40</td>
<td>256</td>
</tr>
</tbody>
</table>

*This figure refers to the CPU resources left for the ESXi kernel to operate.*

Table 14: Example sizing – 4-socket Westmere-EX, 1 TB SAP HANA certified server (2.4 GHz)

Table 15 shows an example for non-production environments: In this example a CPU socket gets used by two in parallel running SAP HANA VM’s.

<table>
<thead>
<tr>
<th>PHYSICAL SERVER</th>
<th>CPUs</th>
<th>pCOREs</th>
<th>TOTAL pCOREs</th>
<th>RAM IN GB</th>
<th>SAPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-socket server</td>
<td>4</td>
<td>15</td>
<td>60</td>
<td>2048</td>
<td>133800</td>
</tr>
<tr>
<td>SAP HANA virtual machines (VMs)</td>
<td>Sockets (CPU) vCPU (cores) Total vCPUs</td>
<td>RAM in GB</td>
<td>SAPS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SoH VM 1</td>
<td>2</td>
<td>10</td>
<td>20</td>
<td>1024</td>
<td>33790</td>
</tr>
<tr>
<td>BWoH VM 2</td>
<td>2</td>
<td>15</td>
<td>30</td>
<td>512</td>
<td>50680</td>
</tr>
<tr>
<td>BWoH VM 3</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>128</td>
<td>8440</td>
</tr>
<tr>
<td>SoH VM 4</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>256</td>
<td>8440</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>60</td>
<td>1920</td>
<td>101350</td>
</tr>
</tbody>
</table>

**Remaining Resources for vSphere ESXi**

<table>
<thead>
<tr>
<th>CPUs</th>
<th>Hyperthreads</th>
<th>Total Hyperthreads</th>
<th>RAM in GB</th>
<th>SAPS*</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESXi Kernel</td>
<td>4</td>
<td>10</td>
<td>60</td>
<td>128</td>
</tr>
</tbody>
</table>

*This figure refers to the CPU resources left for the ESXi kernel to operate.*

Table 15: Non-production example sizing – 4-socket Ivy Bridge-EX, 2 TB SAP HANA certified server (2.8 GHz)

**Storage Sizing for SAP HANA virtualized systems**

The amount of supported SAP HANA VMs, which will run in parallel on a single vSphere host is limited by the IO capacity of the used storage. As with RAM and CPU resources, overcommitting of IO is not supported.

SAP has defined KPIs for Data Throughput and Latency for Production SAP HANA systems, which are the minimum values, required for successful certification of production SAP HANA systems.

Pre-configured SAP HANA appliance servers fulfill these KPIs for a single SAP HANA instance. When more then one SAP HANA production VM should run on such an appliance configuration, then it is required to increase the IO capacity of this pre-configured HANA appliance.
For development and test SAP HANA instances these storage requirements are not requested by SAP, but recommended.

Depending on how many SAP HANA instances/virtual machines should run on a single server, these KPIs need to get multiplied by the SAP HANA production VMs.

SAP has released a special tool, the SAP HANA HW Configuration Check Tool, to measure if the used storage is able to deliver the required KPIs for Data Throughput and Latency for Production SAP HANA systems. If the available storage IO capacity of the selected SAP HANA appliance server is not sufficient, then the local storage capacity needs to get upgraded accordingly to the appliance vendor’s guidelines.

As already discussed in a previous section of this document, another deployment method for SAP HANA is the SAP HANA Tailored Datacenter Integration (TDI) delivery method.

TDI allows using an external storage, which is required for the most advanced VMware features like vMotion or VMware HA. Also, with an external storage the SAP HANA required KPIs for Data Throughput and Latency are easier to met and configure, therefore the most customers that will virtualized SAP HANA may want to select a TDI configuration instead of a pre-configured SAP HANA appliance.

For more details about this check utility and the storage KPIs for production SAP HANA instances, please refer to SAP note 1943937.

3 “SAP_HANA_Hardware_Configuration_Check Tool_v1.4.pdf”
Appendix A: Troubleshooting vSphere Related Issues

Open a Support Request Ticket

If it appears that VMware vSphere is not configured optimally and it is the cause of a bottleneck, file a support request on My VMware at: http://www.vmware.com/support/contacts/file-sr.html.

In addition:

• Follow the troubleshooting steps are outlined in “Troubleshooting ESX/ESXi virtual machine performance issues (2001003)” at: http://kb.vmware.com/kb/2001003.

• Verify that all of the best practices have been applied. See “Performance Best Practices for VMware vSphere 5.5” at: http://www.vmware.com/pdf/Perf_Best_Practices_vSphere5.5.pdf.

• Run the vm-support utility, and then execute the following command at the service console: vm support s. This command collects necessary information that VMware uses to help diagnose the issue. It is best to run this command when symptoms occur.

• For more information, see the “Resources” section near the end of this paper.

Troubleshooting Techniques for vSphere with vCenter and esxtop

Troubleshooting techniques for vSphere with vCenter and esxtop are described in the sections below.

Using vCenter Charts and vSphere Monitoring


esxtop Primer

For detailed information about esxtop metrics, see “Interpreting esxtop Statistics” at: https://communities.vmware.com/docs/DOC-9279.

In addition, a summary of the metrics that can be used for troubleshooting is provided in the table below.

<table>
<thead>
<tr>
<th>DISPLAY</th>
<th>METRIC</th>
<th>THRESHOLD</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>%RDY</td>
<td>10</td>
<td>Over-provisioning of vCPU, excessive usage of vSMP, or a limit (check %MLMTD) is set. This %RDY value is the sum of all vCPUs %RDY for a virtual machine. For example, if the maximum value of %RDY of 1 vCPU is 100%, then 4 vCPUs is 400%. If %RDY is set to 20 for 1 vCPU, then it is problematic because it means that 1 vCPU is waiting 20% of the time for the VMkernel to schedule it.</td>
</tr>
<tr>
<td>CPU</td>
<td>%CSTP</td>
<td>3</td>
<td>Excessive use of vSMP. Decrease the amount of vCPUs for this particular virtual machine.</td>
</tr>
<tr>
<td>CPU</td>
<td>%MLMTD</td>
<td>0</td>
<td>If larger than 0, the worlds are being throttled. The possible cause is a limit on CPU.</td>
</tr>
<tr>
<td>CPU</td>
<td>%SWPWT</td>
<td>5</td>
<td>Virtual machine waiting on swapped pages to be read from disk. This can indicate overcommitted memory.</td>
</tr>
<tr>
<td>MEM</td>
<td>MCTLSZ</td>
<td>1</td>
<td>If larger than 0, the host is forcing the virtual machine to inflate the balloon driver to reclaim memory because the host is overcommitted.</td>
</tr>
<tr>
<td>MEM</td>
<td>SWCUR</td>
<td>1</td>
<td>If larger than 0, the host has swapped memory pages in the past. The host might be overcommitted.</td>
</tr>
<tr>
<td>MEM</td>
<td>SWR/s</td>
<td>1</td>
<td>If larger than 0, the host is actively reading from swap. This is caused by excessive memory overcommitment.</td>
</tr>
<tr>
<td>MEM</td>
<td>SWW/s</td>
<td>1</td>
<td>If larger than 0, the host is actively writing to swap. This is caused by excessive memory overcommitment.</td>
</tr>
</tbody>
</table>
**DISPLAY** | **METRIC** | **THRESHOLD** | **DESCRIPTION**
--- | --- | --- | ---
MEM | N%L | 80 | If less than 80, the virtual machine is experiencing poor NUMA locality. If the virtual machine has memory size greater than the amount of memory local to each processor, the ESXi scheduler does not attempt to use NUMA optimizations for that virtual machine.

NETWORK | %DRPTX | 1 | Dropped packages are being transmitted, hardware is overworked due to high network utilization.

NETWORK | %DRPRX | 1 | Dropped packages are being received, hardware is overworked due to high network utilization.

DISK | GAVG | 25 | Look at DAVG and KAVG as GAVG = DAVG + KAVG.

DISK | DAVG | 25 | At this level, there is disk latency and likely it is caused by storage array.

DISK | KAVG | 2 | Disk latency caused by the VMkernel. High KAVG usually means queuing. Check QUED.

DISK | QUED | 1 | Queue has max’ed out. Possibly queue depth is set too low. Check with the array vendor for the optimal queue value.

DISK | ABRTS/s | 1 | Aborts are issued by the virtual machine because the storage is not responding. For Windows virtual machines, this happens after a 60-second default. This issue can be caused by path failure, or when the storage array is not accepting I/O.

DISK | RESET/s | 1 | The number of command resets per second.

Table 16: esxtop Primer metrics for troubleshooting

**Resources**

For more information about the SAP HANA and VMware products and technologies discussed in this paper, review the links and references below.

**VMware References**

**VMware vSphere**

• Configuring disks to use VMware Paravirtual SCSI (PVSCSI) adapters (1010398): http://kb.vmware.com/kb/1010398
• Server & Datacenter Virtualization Products: http://www.vmware.com/products/data center-virtualization/
• Featured VMware Documentation Sets: http://www.vmware.com/support/pubs/

General Information
• VMware web site: http://www.vmware.com/
• VMware Licensing Help Center: http://www.vmware.com/support/licensing/
• VMware Community, VMware Technology Network (VMTN): https://communities.vmware.com/community/vmtn
• VMware Community, VMware Knowledge Base: http://communities.vmware.com/community/vmtn/resources/knowledgebase
• VMware Best Practices web site: https://communities.vmware.com/community/vmtn/bestpractices
• VMware Support Insider: http://blogs.vmware.com/kbtv/
• VMware TV: http://www.youtube.com/user/vmwaretv
• VMworld TV: http://www.youtube.com/user/VMworldTV
• VMware KBTV (external): http://www.youtube.com/user/VMwareKB

SAP HANA References
• SAP Community Network Landing Page: SAP on VMware: http://scn.sap.com/docs/DOC-27384
• SAP Web site: http://www.sap.com
• SAP HANA running on VMware vSphere VMs: (Note that accessing this paper requires your standard SAP support portal credentials.) https://websmp130.sap-ag.de/sap/support/notes/1788665
• SAP HANA is a completely re-imagined platform for real-time business: http://www.saphana.com/welcome
• Harness the power of SAP HANA In-Memory Computing: http://www.sap.com/pc/tech/in-memory-computing-hana.html
• What is SAP HANA? http://www.saphana.com/docs/DOC-2272
• Overview - SAP HANA tailored data center integration: http://www.saphana.com/docs/DOC-3633
• SAP HANA Master Guide: http://www.saphana.com/docs/DOC-3817

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