Red Hat – Industry Standard Benchmarks

SAP SD Benchmark running in a VM – Leadership Performance using Red Hat Enterprise Linux 6.2 / KVM

40-Core Bare Metal Server		*80-vCPU VM*
SAP SD Benchmark		SAP SD Benchmark
SAP enhancement package 4 for SAP ERP 6.0		SAP enhancement package 4 for SAP ERP 6.0
DB2 9.7		DB2 9.7
Red Hat Enterprise Linux 6.2	→	Red Hat Enterprise Linux 6.2 Guest (80 vCPUs)
		Red Hat Enterprise Linux 6.3 (with integrated KVM Hypervisor)
IBM System x3850 X5 (4 processors/40 cores/80 threads, Intel Xeon Processor E7-8870, 2.4 GHz) with 512 GB RAM	=	IBM System x3850 X5 (4 processors/40 cores/80 threads, Intel Xeon Processor E7-8870, 2.4 GHz) with 512 GB RAM

Version 2.0

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1. Introduction & Executive Summary

1.1 Introduction to Red Hat Enterprise Linux (RHEL) 6 Virtualization

Traditional virtualization products relied on hardware emulation, intercepting and translating hardware requests from the guest virtual machines. This approach created significant overhead, especially for I/O intensive workloads and limited the scalability of the virtual environment. For this reason enterprise class workloads such as databases or ERP systems were seldom virtualized in production.

“Common wisdom” told us that any system that needed high performance, or needed to scale was not a candidate for virtualization – and this was borne out by customer experience. Hence, applications that require low latency or are time sensitive, such as financial trading applications have so far been unable to benefit from virtualization.

Red Hat’s approach to virtualization is easy to adopt because it is delivered as an integral part of the Red Hat Enterprise Linux platform. Based upon kernel-based virtual machine (KVM) technology, Red Hat’s virtualization capabilities are integrated into Red Hat Enterprise Linux and leverage the latest hardware virtualization capabilities provided by Intel and AMD processor platforms. The modular design of Red Hat Enterprise Linux allows customers to choose when and where to use virtualization. For additional flexibility, customers can deploy both Red Hat Enterprise Linux and Microsoft Windows as fully supported guests in a Red Hat Enterprise Linux virtualized environment. Red Hat Enterprise Linux also supports multiple virtualization use cases, from hardware abstraction for existing software stacks, to datacenter consolidation, to virtualized clusters and private clouds.

Beyond core virtualization, Red Hat Enterprise Linux offers leading support for advanced virtualized I/O capabilities through SR-IOV and NPIV standards. A standard virtualization management infrastructure, libvirt, developed by Red Hat and adopted by other operating systems, provides a flexible interface for defining, managing, and monitoring virtual machines.

Red Hat Virtualization supports dynamic resource allocation, allowing memory

and CPUs to be dynamically added or removed from the guest. For example, if a guest needs more CPU resources to complete a resource intensive processing job, the user may dynamically add more virtual CPUs (vCPUs), and when the job completes, the extra vCPUs may be reassigned to other guests. Upcoming releases of Red Hat integrated virtualization will support up to 160 vCPUs per virtual machine, allowing even the largest workloads to be virtualized.

1.2 Running the SAP SD Benchmark using RHEL 6 Virtualization

The SAP Sales and Distribution (SD) Standard Application Benchmark has become a de facto standard for evaluating the performance of many ERP solutions. This represents the first time the SAP SD benchmark has been run using Red Hat Enterprise Linux (RHEL) 6.2 Virtualization. Figure 1 shows the configuration benchmarked. The remainder of this section summarizes some of the key results.

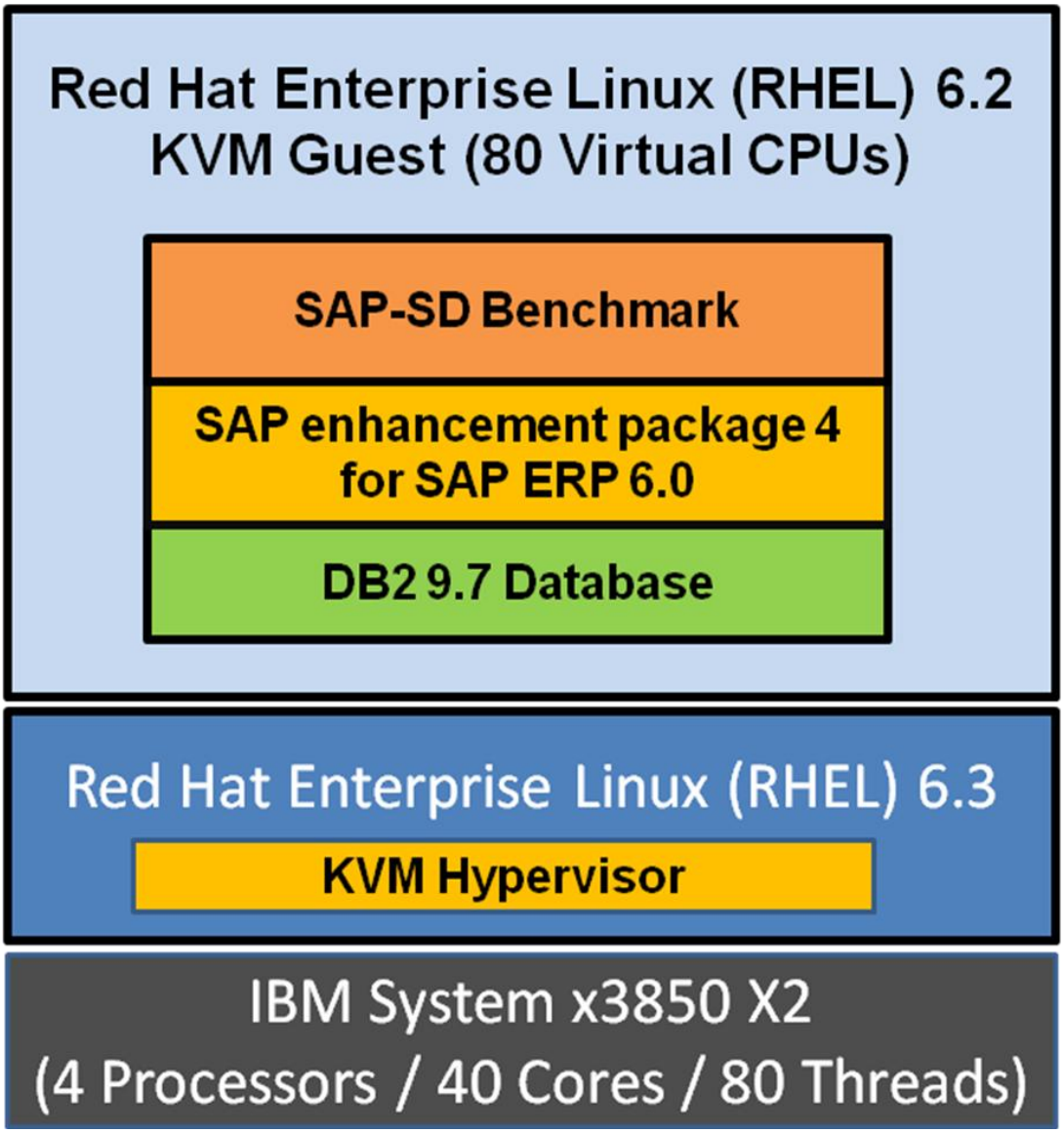

Figure 1: Configuration Benchmarked

1.3 Virtualization Efficiency of RHEL 6 running the SAP SD Benchmark in a Large Guest

As shown in Figure 2, **RHEL 6 / KVM demonstrated excellent virtualization efficiency (of 85%) by achieving an SAP SD benchmark result of:**

- **10,700 SAP SD users using a RHEL 6 / KVM virtual machine versus**
- **12,560 SAP SD users using RHEL 6 on a bare-metal system**

both running on identical hardware.

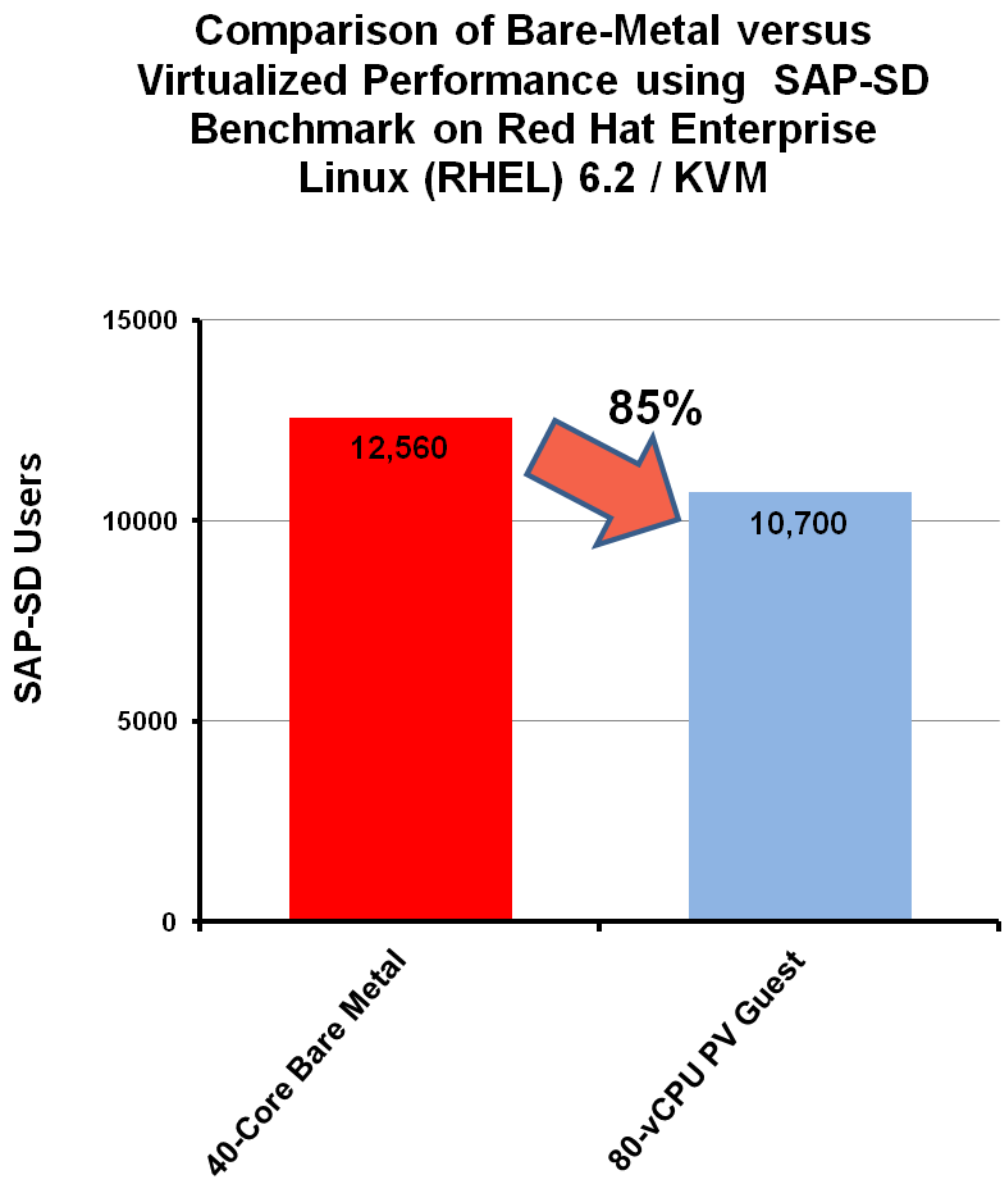

Figure 2: Virtualization Efficiency of SAP SD on Red Hat Enterprise Linux 6.2

The **bare metal SAP SD benchmark result** was achieved in February 2012 using Red Hat Enterprise Linux (RHEL) 6.2:

- **12,560 SAP SD (2-tier) benchmark users** achieved by IBM, with Red Hat Enterprise Linux 6.2 and DB2 9.7 running with SAP ERP 6.0 running on an IBM System x3850 X5, 4 processors / 40 cores / 80 threads, Intel Xeon Processor E7-8870, 2.40 GHz, 64 KB L1 cache and 256 KB L2 cache per core, 30 MB L3 cache per processor. SAP certification number 2012006. [Appendix A.]

The **virtual server SAP SD benchmark result** was achieved in April 2012 by running the benchmark in a Red Hat Enterprise Linux 6.2 / KVM environment using identical hardware as the above bare metal SAP SD bencmark:

- **10,700 SAP SD (2-tier) benchmark users** achieved by IBM, with Red Hat Enterprise Linux 6.2 / KVM (using 1 Virtual Machine = 80 virtual CPUs) and DB2 9.7 running with SAP ERP 6.0 running on an IBM System x3850 X5, 4 processors / 40 cores / 80 threads, Intel Xeon Processor E7-8870, 2.40 GHz, 64 KB L1 cache and 256 KB L2 cache per core, 30 MB L3 cache per processor, 512 GB main memory. SAP certification number 2012020. [Appendix B.]

1.4 SAP SD Benchmark Performance on Competing Virtualization Technologies

As shown in Figure 3, **RHEL 6 / KVM demonstrated the best SAP SD benchmark performance among all published SAP SD results using various virtualization technologies:**

- **10,700 SAP SD users using a RHEL 6.2/KVM virtual machine versus**
- **4,600 SAP SD users using a VMware vSphere 5 virtual machine versus**
- **501 SAP SD users using a Micorsoft Windows Hyper-V virtual machine.**

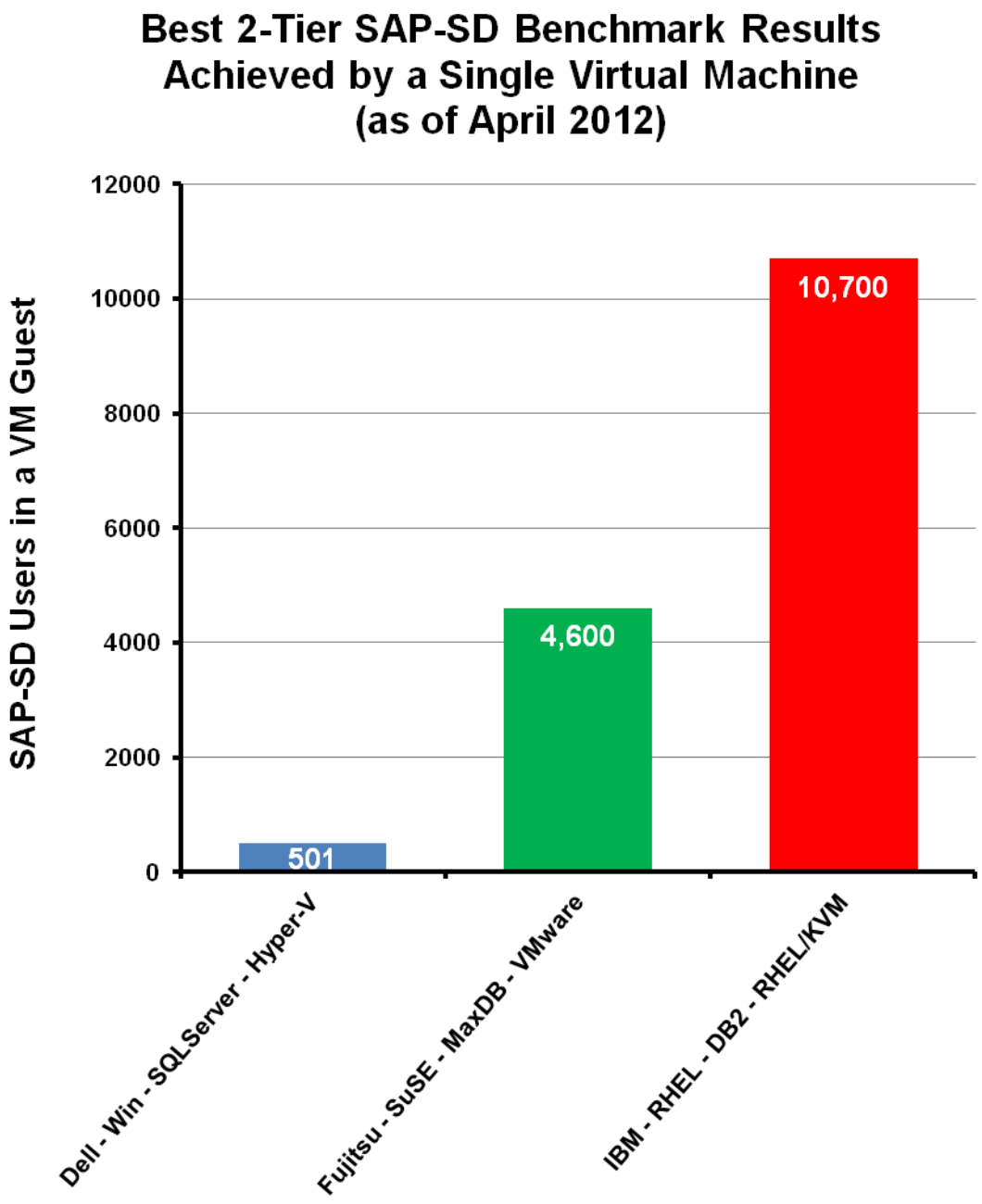

Figure 3: SAP Performance on Competing Virtualization Technologies

- **Best Hyper-V SAP SD benchmark result: 501 SAP SD (2-tier) Benchmark users** achieved by Dell, with Windows Server 2003 Enterprise Edition on Windows 2008 Hyper-V (using 1 Virtual Machine = 2 virtual CPUs) and SQL Server 2005 with SAP ECC 6.0 running on Dell PowerEdge Model R900 (4 Processors / 16 Cores / 16 Threads, Quad-Core Intel Xeon Processor X7350, 2.93 Ghz, 64 KB L1 cache per core and

4 MB L2 cache per 2 cores. 90 GB RAM.) SAP certification number 2008055. [Appendix C.]

- **Best VMware SAP SD benchmark result: 4,600 SAP SD (2-tier) Benchmark users** achieved by VMware, with SuSE Linux Enterprise Server 11 SP1 on VMware vSphere 5.0 (using 1 Virtual Machine = 2 virtual CPUs) and MaxDB 7.8 with SAP ERP 6.0 running on Fujitsu PRIMERGY RX300 S6, 2 processors / 12 cores / 24 threads, Intel Xeon Processor X5690, 3.46 GHz, 64 KB L1 cache and 128 KB L2 cache per core, 12 MB L3 cache per processor, 96 GB main memory. SAP certification number 20110027. [Appendix D.]

For more details, refer to the SAP SD benchmark results site: http://www.sap.com/solutions/benchmark/sd2tier.epx

More details of these and every other SAP benchmark can be found at http://www.sap.com/benchmark.

This benchmark result is a demonstration of the close and continued cooperation between IBM Corp. and Red Hat Inc. to showcase the superior combined performance of Red Hat Enterprise Linux (RHEL) and DB2 running on IBM's Intel Xeon-based System x servers.

2. SAP SD Benchmark Overview

SAP Standard Application Benchmarks help customers and partners find the appropriate hardware configuration for their IT solutions. SAP, working in concert with its hardware partners, has developed the SAP Standard Application Benchmarks to test the hardware and database performance of SAP applications and components.

The benchmarking procedure is standardized and well defined. It is monitored by the SAP Benchmark Council made up of representatives of SAP and technology partners involved in benchmarking. Originally introduced to strengthen quality assurance, the SAP Standard Application Benchmarks can also be used to test and verify scalability, concurrency, and multi-user behavior of system software components, RDBMS, and business applications.

Customers can benefit from the benchmark results in various ways. For example, benchmark results illuminate the scalability and manageability of large installations. The benchmark results:

- Provide basic information to configure and size SAP Business Suite
- Allow users to compare different platforms
- Enable Proof-of-concepts scenarios
- Provide an outlook for future performance levels (new platforms, new servers, and so on)

2.1 Benchmark Description

The SAP SD benchmark can be configured as either two-tier or three-tier. Within the two-tier configuration, the database server and the SAP NetWeaver application server run on the same physical machine. In the three-tier configuration, the presentation tier, application tier, and database tier each run on separate physical servers. This benchmark was run using a two-tier configuration.

In the two-tier configuration architecture the database and application layer reside on a single system – the simulation is driven by the presentation server (aka benchmark driver).

A SAP Standard Application Benchmark consists of script files that simulate the

most typical transactions and workflow of a user scenario. It has a predefined SAP client database that contains sample company data against which the benchmark is run. The benchmark transactions of each component usually reflect the data throughput of an installation (for example orders, number of goods movements, etc.). Note: Each benchmark user has his or her own master data, such as material, vendor, or customer master data to avoid data-locking situations.

The Sales and Distribution benchmark is one of the most CPU intensive benchmarks available and has become a de-facto standard for SAP's platform partners and in the ERP (Enterprise Resource Planning) environment. During the benchmark a defined set of business transactions are run through as shown in the table below.

The SD benchmark driver provided by SAP simulates end users driving business transactions in dialog steps. The Sales and Distribution (SD) Benchmark covers a sell-from-stock scenario, which includes the creation of a customer order with five line items and the corresponding delivery with subsequent goods movement and invoicing. It consists of the following SAP transactions:

Create an order with five line items. (VA01)
Create a delivery for this order. (VL01N)
Display the customer order. (VA03)
Change the delivery (VL02N) and post goods issue.
List 40 orders for one sold-to party (VA05)
Create an invoice. (VF01)

Table 1: Dialog steps of the standard Sales & Distribution (SD) benchmark

2.1.1 SAP Sales and Distribution (SD) Benchmark – 2009 Update

By their very nature, the SAP Standard Application Benchmarks are subject to two contradictory forces: the need for stability and the need for change. It is the stability of the benchmarks that make them reproducible and reliable, and ensure the comparability of the benchmark results over time. At the same time, the benchmarks need to evolve with the SAP applications on which they are based, if they are to retain their applicability, validity and usefulness for SAP

customers.

Business changes constantly, for example, Unicode and the use of the New General Ledger are now common practice for SAP customers across all industries, and the SAP Standard Application Benchmarks need to reflect this change. For this reason, on January 1, 2009, these and a number of other enhancements were implemented for all ERP Benchmarks, most notably the SAP Sales and Distribution (SD) benchmark (2-tier, 3-tier, and SD Parallel) and introduced with SAP enhancement package 4 for SAP ERP 6.0 of SAP Business Suite 7, The updates are transparent, that is, the steps of the benchmark scenario remain unchanged.

Important note: These changes make the SD benchmark more resource-intensive which has a direct impact on the benchmark results. In detail, the updates are:

- Unicode: All benchmarks now must use a Unicode codepage
- Sub-second response time: The response time for the SD benchmark must now be below one second (vs. below 2 seconds as previously required)
- Use of the New General Ledger
- Activation of Credit Limit Check functionality

2.2 Benchmark Methodology

Each of the simulated users repeats this series of transactions from the start to the end of a benchmark run. During the so-called ramp-up phase the number of concurrently working users is increased until the expected limit (e.g. 5000) is reached. When all users are active the test interval starts. This **performance level must be maintained for at least 15 minutes** (benchmark rule). After at least 5 minutes of the high load phase one or more database checkpoints must be forced (i.e. all log file data is flushed back to the database) to stress the I/O subsystem in a realistic way (benchmark rule). At the end of the high load phase users are gradually taken off the system until none is active. When the test concludes all relevant data (some are gathered with a SAP developed Operating System monitor) are then transferred to the presentation server for further evaluation.

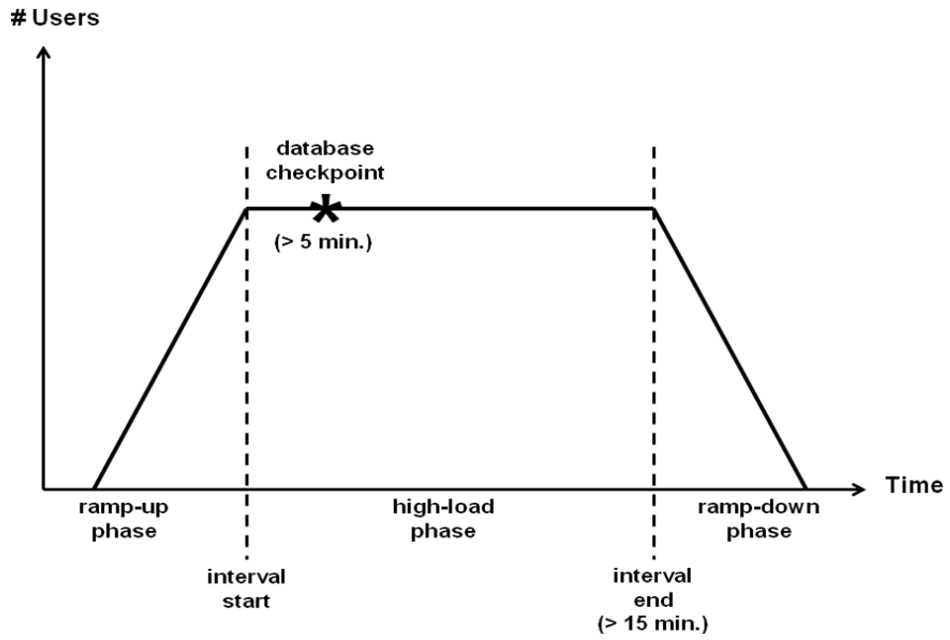

Figure 4: Benchmark Run

The SAP Standard Application Benchmarks measure all performance relevant metrics such as database request times, wait times, CPU utilization, average dialog response times by a given number of benchmark users (with a fixed **think time of 10 seconds** between each dialog step) and the achieved throughput.

2.3 Key Performance Metrics

2.3.1 Benchmark Users and Average Dialog Response Time

A benchmark can only be certified if the **average dialog response time is less than one second** (this is the number which some time ago was accepted as a tolerable system reaction time). More and more benchmark users are 'switched' to the system under test until the response time is outside the granted time frame.

Only SAP certified and audited benchmarks may be published by partners to ensure results that can be fairly compared with each other. A typical result would read like '5000 SD benchmark users with an average dialog response time of 0.98 seconds'.

2.3.2 Throughput Measurement in SAPS

SAP has defined a unit for measuring throughput in a SAP Business Suite environment: SAPS (SAP Application Benchmark Performance Standard).

100 SAPS are defined as 2,000 fully processed business line items per hour in the standard SD application benchmark. This throughput is achieved by processing 6,000 dialog steps (screen changes) and 2,000 postings per hour in the SD benchmark or processing 2,400 SAP transactions.

In the SD standard benchmark 'fully business processed' means the full business workflow of an order line item (creating the order, creating a delivery note for this order, displaying the order, changing the delivery, posting a goods issue, listing orders and creating an invoice) has completed.

2.4 What must be published

The following information must be part of a benchmark press release:

- Type of client/server configuration (2-tier or 3-tier)
- RDBMS type and version number
- Operating System type and version number
- The exact name of the SAP business software components and release

numbers used in the benchmark certificate must be included

- Number of tested benchmark users
- Average dialog response time in ‘n.nn sec’
- Achieved throughput in dialog steps / hour
- A detailed description of hardware configuration (type, size of main memory, average CPU utilization and function for all servers involved in the benchmark)
- Confirmation that the benchmark is certified by SAP (e.g. "This benchmark fully complies with SAP's issued benchmark regulations and has been audited and certified by SAP.")
- Reference where readers can get more information (e.g. "Details regarding this benchmark are available upon request from hardware partner or SAP AG.").

3. System Configuration

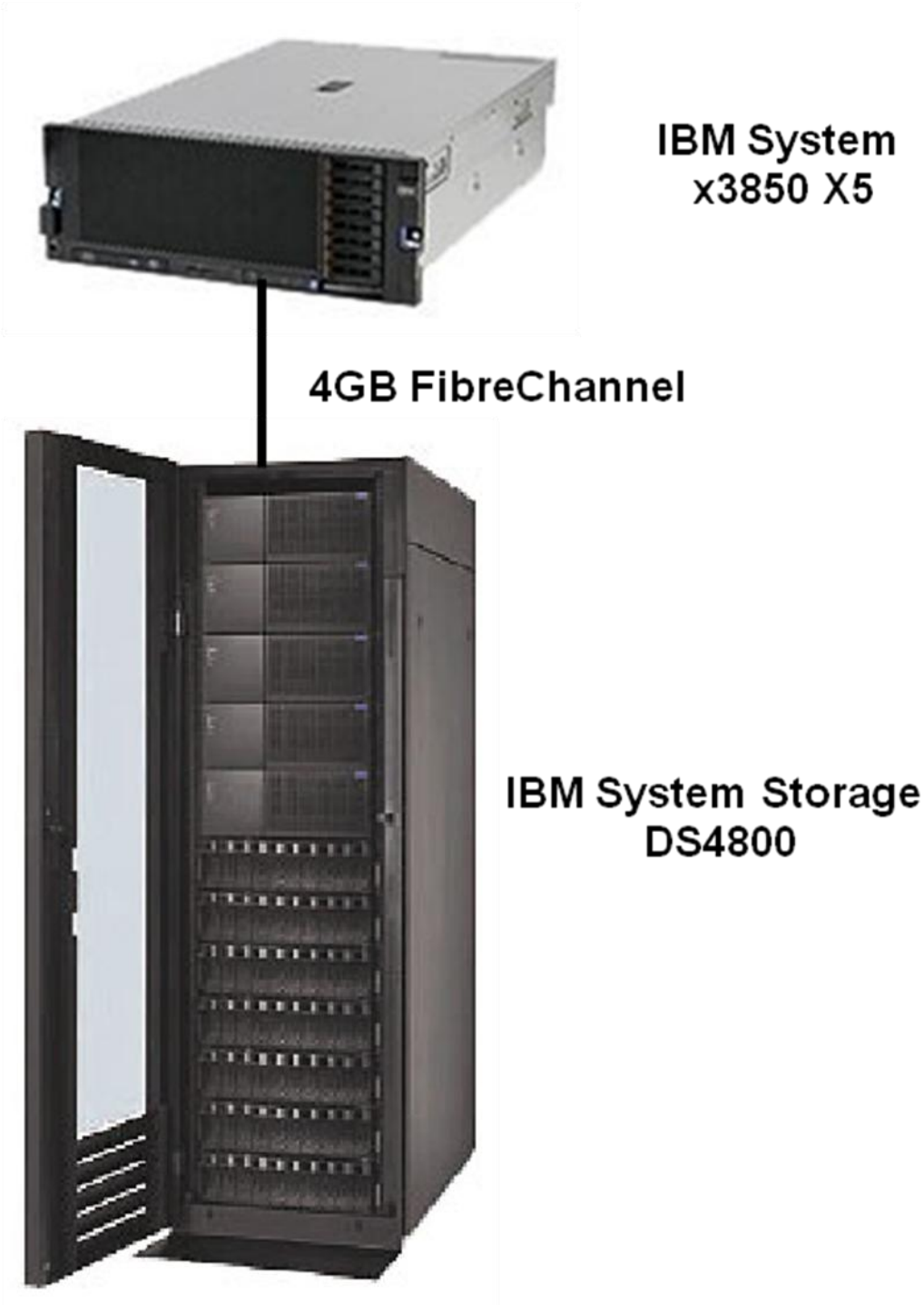

Figure 5: Hardware Configuration

3.1 Hardware Configuration

3.1.1 Server / OS Configuration (DB & Application Server)

Product name of the server	IBM System x3850 X5
IBM System x3850 X5	Intel Xeon E7-8870, 2.40GHz, 4 Processors, 40 Cores, 80 Hyper Threads
Caches	L1 Cache = 64KB/Core, L2 Cache = 256 KB/Core, L3 Cache = 30 MB/Core
Operating System	Red Hat Enterprise Linux 6.2 x64

3.1.2 I/O Subsystem & Storage

Storage Architecture	1. Local SAS storage 2. IBM System Storage DS4800 (3 controllers)
Total number of physical disk drives	167
Total database disk space	457 GB
Controller type, # of physical disk drives per controller, RAID Level	Local SAS, 1 drive, no RAID Fibre Channel 0, 134 drives, RAID 0 Fibre Channel 1, 16 drives, RAID 5 Fibre Channel 1, 16 drives, RAID 0

3.2 Software Configuration – Running on Bare Metal

Software Configuration:

- Red Hat Enterprise Linux 6.2
- SAP enhancement package 4 for SAP ERP 6
- DB2 v9.7

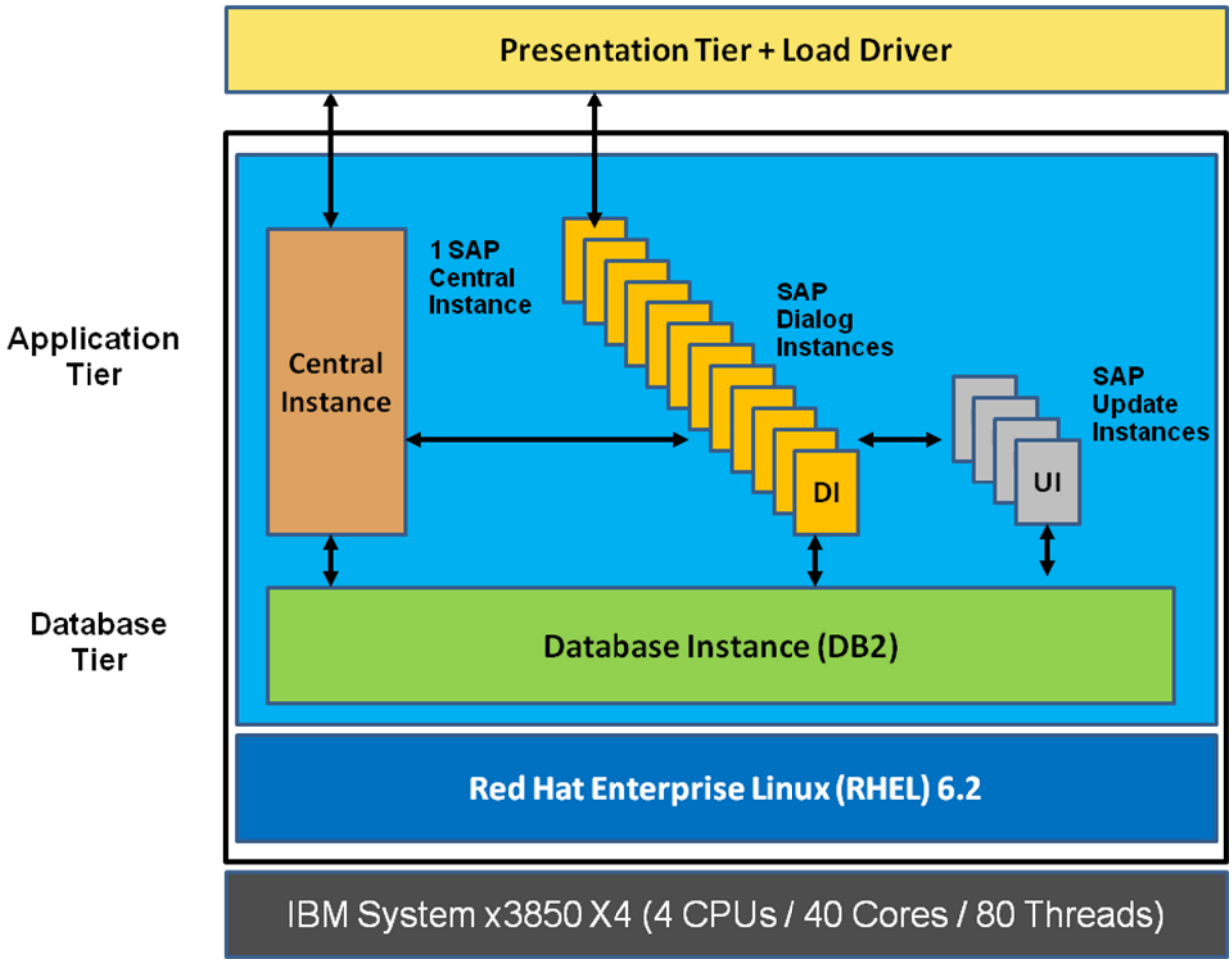

Figure 2: Software Configuration

3.3 Software Configuration – Running in Virtual Machine

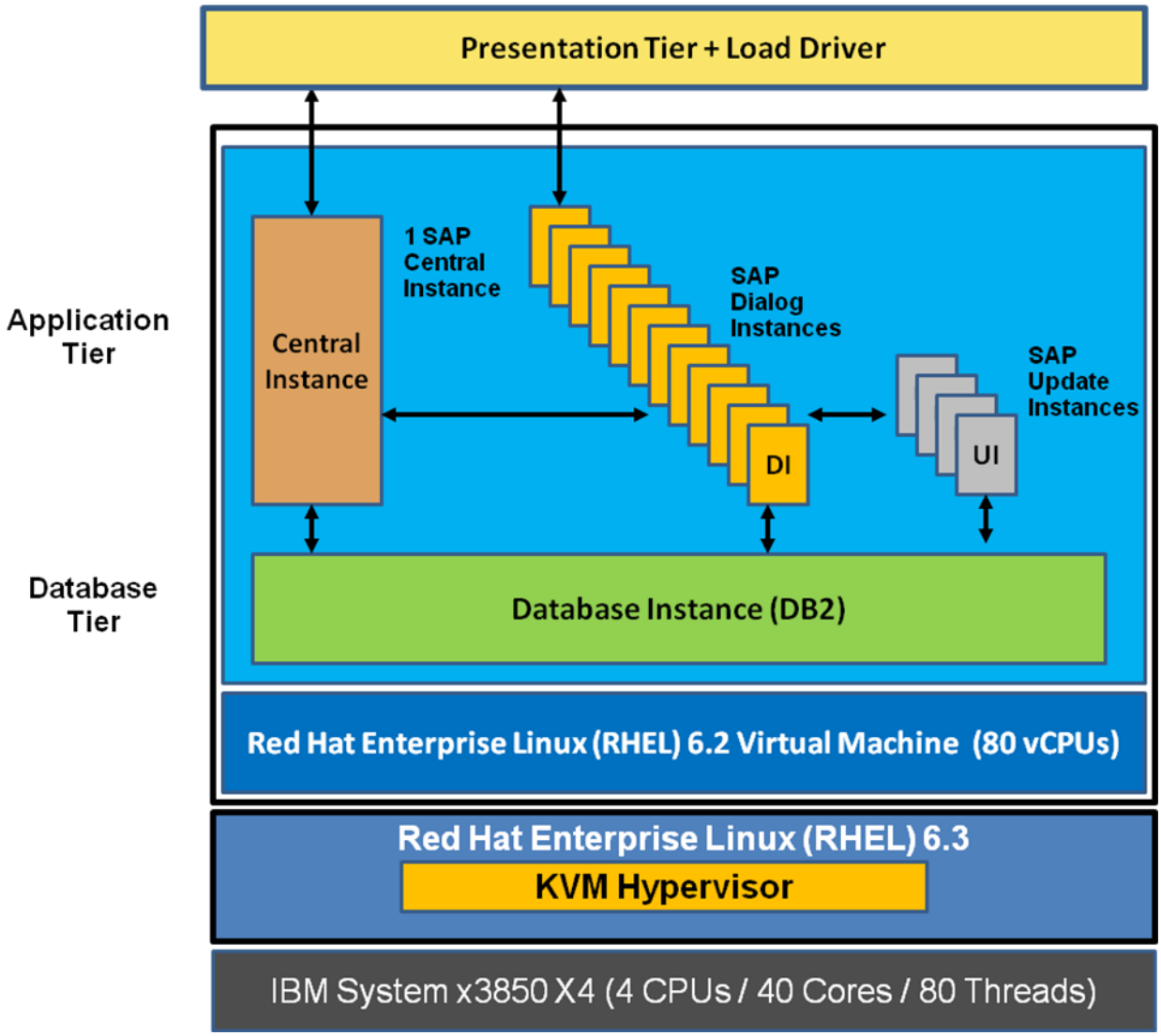

Figure 8: SAP SD Benchmark running in RHEL 6.2 Guest

4. Configuration Steps & Tuning

4.1 Red Hat Enterprise Linux Tuning

Red Hat Enterprise Linux can support hardware large page enablement through the use of kernel parameter settings. For this benchmark, 25,000 2MB pages were configured to be used by SAP and DB2, providing a slight increase in performance over using the default 4K page size.

4.2 DB2 Database Tuning

The database was tuned to provide sufficient buffer cache to allow the database to perform with 99%+ database buffer access.

The database log device was created on a large striped volume on the DS4800. The log file itself was created on this volume using the ext4 file system.

Another volume was used to hold the “hot” tables that were accessed extensively in the operation of the benchmark. This allowed for custom tuning of the table parameters and to separate the I/O of these tables from the rest of the database activity.

The VBDATA tables (VBDATA, VBMOD and VBHDR) were also separated out from their default tablespace and put on a different LUN that allowed for less contention with the core database activity and to allow for a custom buffer pool to be used to hold the contents of those tables for faster transaction processing.

4.3 SAP Tuning

After the initial installation of the SAP environment, which included the installation of the SAP central instance (CI) and 31 dialog/update instances, the environment was tuned to set up the appropriately sized buffers and work processes. The final configuration split off a central enque instance for faster enque processing. Each SAP instance was configured to perform update processing locally to the instance. These changes allowed for better resource allocation for the SD benchmark workload.

SAP instances were divided up equally among the available four physical processors and then configured to use local memory and processing resources. This was accomplished by using the numactl operating system utility to start and hold each SAP instance on a particular processor.

5. Benchmark Performance Results

Number of SAP SD benchmark users		10,700
Average dialog response time		0.93 seconds
Throughput	Fully processed order line items per hour	1,175,000
	Dialog steps per hour	3,525,000
	SAPS	58,750
Average database request time	Dialog	0.024 seconds
	Update	0.045 seconds
CPU utilization of central server		99%
Operating system, central server		Red Hat Enterprise Linux 6.2 / KVM
RDBMS		DB2 9.7
SAP Business Suite software		SAP enhancement package 4 for SAP ERP 6.0

Table 3: SAP-SD Benchmark Results for RHEL 6.2 / KVM System

6. References

1. SAP Sales and Distribution (SD) Benchmark
   http://www.sap.com/solutions/benchmark/sd.epx

2. SAP SD Standard Application Benchmark - Published Results, Two-Tier Internet Configuration http://www.sap.com/solutions/benchmark/sd2tier.epx

Appendix A: RHEL 6.2 Bare Metal – SAP SD Result Certification

CERTIFICATION

SAP® Standard Application Benchmarks

The SAP Sales and Distribution (SD) Standard Application Benchmark performed on February 7, 2012, by IBM in Research Triangle Park, NC, USA, was certified on February 15, 2012, with the following data:

Number of SAP SD benchmark users:	12,560
Average dialog response time:	0.99 seconds
Throughput:	
Fully processed order line items per hour:	1,371,670
Dialog steps per hour:	4,115,000
SAPS:	68,580
Average database request time (dialog/update):	0.016 sec / 0.031 sec
CPU utilization of central server:	98%
Operating system, central server:	Red Hat Enterprise Linux 6.2
RDBMS:	DB2 9.7
SAP Business Suite software:	SAP enhancement package 4 for SAP ERP 6.0

Configuration:

Central server: IBM System x3850 X5, 4 processors / 40 cores / 80 threads, Intel Xeon Processor E7-8870, 2.40 GHz, 64 KB L1 cache and 256 KB L2 cache per core, 30 MB L3 cache per processor, 512 GB main memory

Certification number: 2012006

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Appendix B: RHEL 6.2/KVM – SAP SD Result Certification

CERTIFICATION

SAP® Standard Application Benchmarks

The SAP Sales and Distribution (SD) Standard Application Benchmark performed on April 13, 2012 by IBM in Austin, TX, USA, was certified on April 20, 2012, with the following data:

Number of SAP SD benchmark users:	10,700
Average dialog response time:	0.93 seconds
Throughput:	
Fully processed order line items per hour:	1,175,000
Dialog steps per hour:	3,525,000
SAPS:	58,750
Average database request time (dialog/update):	0.024 sec / 0.045 sec
CPU utilization of central server:	99%
Operating system:	Red Hat Enterprise Linux 6.2 on KVM
RDBMS:	DB2 9.7
SAP Business Suite software:	SAP enhancement package 4 for SAP ERP 6.0

Configuration:

No. of servers	Usage	Hardware	Segmentation / CPU utilization in virtual machines
1	Central server	IBM System x3850 X5, 4 processors / 40 cores / 80 threads, Intel Xeon Processor E7-8870, 2.40 GHz, 64 KB L1 cache and 256 KB L2 cache per core, 30 MB L3 cache per processor, 512 GB main memory	1 virtual machine (VM) using 80 virtual CPUs CPU utilization of VM1 (DB/Dia/Upd/Msg/Enq): 94%

Certification number: 2012020

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Appendix C: Hyper-V – SAP SD Result Certification

CERTIFICATION

SAP Standard Application Benchmarks

The SAP SD standard SAP ERP 6.0 (2005) application benchmark performed on August 07, 2008 by Dell in Walldorf, Germany was certified on September 30, 2008 with the following data:

Number of benchmark users & comp.:	501 SD (Sales & Distribution)
Average dialog response time:	1.72 seconds
Throughput:	
Fully processed order line items / hour:	51,330
Dialog steps / hour:	154,000
SAPS:	2,570
Average DB request time (dia/upd):	0.016 sec / 0.012 sec
CPU utilization of central server:	13%
CPU utilization inside virtual machine:	99%
Operating System central server:	Windows Server 2003 Enterprise Edition on Windows 2008 Hyper-V (using 2 virtual CPUs)
RDBMS:	SQL Server 2005
SAP ECC Release:	6.0

Configuration:

Central server: Dell PowerEdge Model R900, 4 processors / 16 cores / 16 threads, Quad-Core Intel Xeon Processor X7350, 2.93 GHz, 64 KB L1 cache per core and 4 MB L2 cache per 2 cores, 88 GB main memory

Certification Number. 2008055

Appendix D: VMware vSphere 5.0 – SAP SD Result Certification

CERTIFICATION

SAP® Standard Application Benchmarks

The SAP Sales and Distribution (SD) Standard Application Benchmark performed on July 19, 2011, by Fujitsu in Walldorf, Germany, was certified on August 02, 2011, with the following data:

Number of SAP SD benchmark users:	4,600
Average dialog response time:	0.99 seconds
Throughput:	
Fully processed order line items per hour:	502,330
Dialog steps per hour:	1,507,000
SAPS:	25,120
Average database request time (dialog/update):	0.017 sec / 0.029 sec
CPU utilization of central server:	98%
Operating system, central server:	SuSE Linux Enterprise Server 11 SP1 on VMware vSphere 5.0
RDBMS:	MaxDB 7.8
SAP Business Suite software:	SAP enhancement package 4 for SAP ERP 6.0

Configuration:

No. of servers	Usage	Hardware	Segmentation / CPU utilization in virtual machines
1	Central server	Fujitsu PRIMERGY RX300 S6, 2 processors / 12 cores / 24 threads, Intel Xeon Processor X5690, 3.46 GHz, 64 KB L1 cache and 128 KB L2 cache per core, 12 MB L3 cache per processor, 96 GB main memory	1 virtual machine (VM) using 24 virtual CPUs CPU utilization of VM1 (DB/Dia/Upd/Msg/Enq): 98%

Certification number: 2011027

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