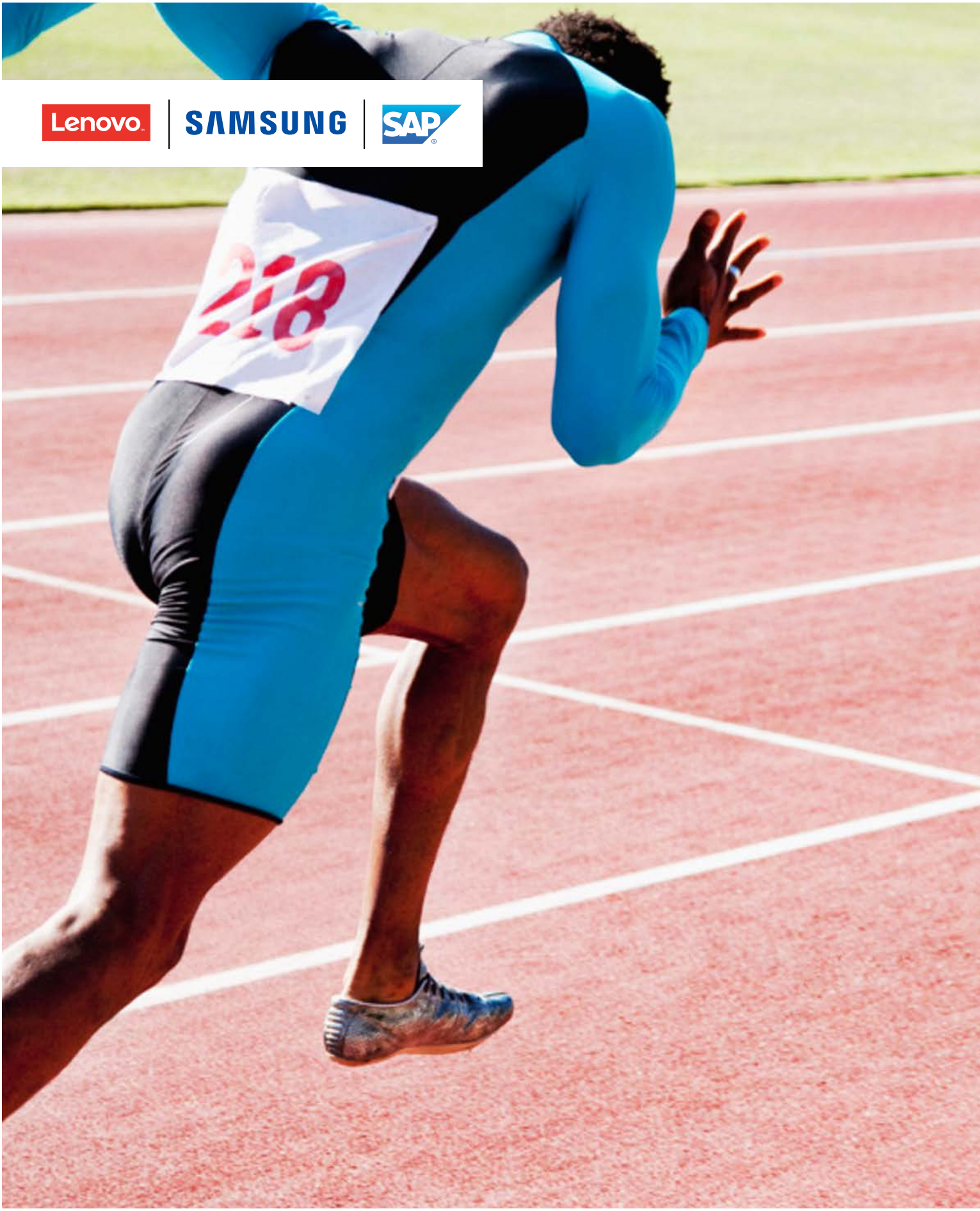
Boosting the Performance of SAP® S/4HANA

With the Latest Technology from Lenovo and Samsung



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Introduction

More than ever, running a business today requires thorough availability, transparency, and connectivity of business data, as well as the ability to simulate planning and decision making and to take immediate action on the results. To stay ahead of the competition, businesses continuously need to innovate their business models and processes while controlling their IT costs. To do so, an IT architecture that safeguards simplification, performance, and flexibility is essential. SAP® S/4HANA, a next-generation business suite, leverages the innovative in-memory technology of the SAP HANA® platform to help businesses Run Simple in the Digital Economy. This paper examines the impact of Samsung's latest DRAM technology, built into Lenovo's cutting-edge servers, for a typical environment of SAP S/4HANA, from both a performance and an ecological footprint point of view.

A Proof of Concept:

Improved Performance and Power Consumption

By eliminating the divide between transactions and analytics through its revolutionary in-memory technology, the SAP HANA platform allows people to respond to business questions anywhere in real time. Real-time and predictive analytics, spatial processing, and data virtualization can be placed on the same architecture, which makes redundant data and servers a thing of the past. Applications get accelerated without manual intervention and tuning, enabling predictable response times for ad hoc queries. As a result, you can get the full picture of your business in real time and answer all data-discovery questions without special data tweaking, while gaining the ability to update the same copy of data in real time.

SAP S/4HANA dramatically accelerates business processes and simplifies IT landscapes, software deployment, and innovation. It can be deployed in the cloud, on premise, or in a hybrid model. As the next-generation business suite, SAP S/4HANA leverages the innovative in-memory technology of SAP HANA to the fullest extent. This is why high-end hardware components are a critical prerequisite for a well-performing SAP S/4HANA software environment. At the same time, energy consumption becomes increasingly important as an influencer for the total cost of ownership (TCO) of running a data center.

In this proof-of-concept paper, we specifically explore the impact of Samsung's latest 3DS/TSV (3-Dimensional Stacked IC/Through-Silicon Via) DRAM technology, built into Lenovo's cutting-edge servers based on the sixth generation of Enterprise X-Architecture® technology running on Intel Haswell processors, for a typical usage scenario for SAP S/4HANA.

We begin with a look at the value of this approach throughout the enterprise. We examine the value for the business as a whole, which gains agility; for IT, through a simplified landscape; and for the end user, who enjoys a personalized real-time experience for everyday work. The paper goes on to describe the software that was tested, explaining how in-memory technology from SAP works. It describes the Lenovo System x3850/x3950 X6 server and Samsung 3DS/TSV memory, with a brief overview of the Intel Haswell-EX as the processor of choice. It concludes with the test results and an analysis of those results that show their value to real-world implementations, which include significant gains in power consumption and performance. Our purpose is to help IT decision makers understand which technology platform is best suited for hosting SAP S/4HANA.

A Look at the Wide-Ranging Value of This Approach

Organizations of all types and sizes maintain increasingly large data stores, which are the source of essential information to support business activities and decision making. By speeding up analytical processing and application response time, organizations can make full use of this information to increase their overall agility. This can help them better understand customer behavior, for example, predict demand, and uncover new revenue opportunities. Organizations can provide business-people across the enterprise with better decision support, and empower people to get answers and respond to queries in real time.

With SAP S/4HANA, organizations gain this and much more. The IT team can take advantage of a simplified IT architecture and landscape, reduced data footprint, and flexible deployment

options. Individual departments benefit from increased capacity of their workforce, accelerated business processes, lower total cost of ownership, and increased transparency and insight into their operations. The end user discovers unprecedented personalization of work space, with the SAP Fiori® user experience (UX) providing a consistent interface across all tasks and devices.

For this proof-of-concept paper, a high-volume order-to-cash scenario implemented by the SAP ERP powered by SAP HANA application will be used to demonstrate the impact of the top-scoring technology platform provided by Samsung and Lenovo for an SAP S/4HANA software environment.

Overview of Core Findings

- Efficiency improvements with up to 28.6% less energy consumption for a DDR4/Haswell configuration, compared to DDR3/Haswell
- Increased low-level memory bandwidth between 11% and 20% across all access patterns, with power consumption benefits of around 25% on average
- Benefits for SAP HANA from a DDR4/Haswell configuration by reduced CPU consumption, resulting in more workload and operational flexibility

SAP Software Applications

The SAP HANA platform is an in-memory column-store database platform that runs massively parallel across multiple nodes in a clustered configuration. Unlike many other solutions in the marketplace, SAP HANA is not just an indexing solution to enhance what is essentially a disk-based, OLTP database engine; it was built from the ground up as an in-memory solution. It brings transactional and analytical processing together into a single platform and dramatically lowers the data footprint with its sophisticated data model and data compression technique. This innovative architecture enables a completely new way of designing and developing business applications such as SAP S/4HANA, and results in unprecedented operational speed and a simplified IT landscape, among other benefits. The more powerful your hardware platform is, the better it can leverage the capabilities of solutions based on SAP HANA, and the more flexibility it can offer for right-sizing your IT environment and optimizing your IT TCO.

> "Samsung's new 3DS memory offerings provide the high throughput and capacity needed for real-time processing while significantly reducing power consumption. Built into Lenovo's newest server platform, these modules allow even more-efficient processing in SAP HANA and together create a sustainable solution that not only lowers TCO but also contributes to 'green IT.'"
>
> **Daniel Schneiss, Senior Vice President, Global Head of SAP HANA Platform and Databases, SAP**

Lenovo Server Platform

The Lenovo System X6 server is provided in the form of two base building blocks: x3850 X6 with up to four-socket 4U, and x3950 X6 with up to 8 processor sockets in an 8U form factor. These rack-mounted servers represent the sixth generation of the Enterprise X-Architecture. They are designed to help businesses better manage their growing volume of data, regardless of constrained capital and operational resources. X6 platforms, with Intel Xeon processors E7-8800 v3 series, can produce up to 56% faster compute performance than the previous generation of X6 systems with last-generation processors. Yet these X6 platforms accommodate multiple generations of Intel processors (Xeon CPUs, code-named IvyBridge; Haswell; and the next generation) and memory technology (DDR3 and DDR4) in the same chassis.

The X6 portion delivers large-application virtualization and decreases infrastructure costs and complexity, thanks to a combination of new storage and memory technologies. With its agile, modular “book” design, X6 is a resilient platform that supports mission-critical databases, enterprise applications, and virtualized environments.

The X6 servers pack numerous fault-tolerant and high-availability features into a high-density, rack-optimized lidless package that helps reduce the space needed to support massive network computing operations and simplify servicing. It supports up to four Intel Xeon E7 v3 and v2 high-performance processors and up to 12 TB of memory and 144 cores of processing power.

Customers can start small with an x3850 X6 dual-processor system and eventually upgrade to four processors. Such a system can even be upgraded from 4U to 8U (x3950 X6) while maintaining all processor, storage, and I/O books. A server installation (operating system and applications) can be maintained through such upgrades. In addition, the processor books can be upgraded from E7 v2 (IvyBridge) to E7 v3 (Haswell) in the future, and also to the next Intel processor generation. Memory modules can be maintained with an upgrade from IvyBridge to Haswell to improve overall cost for such an upgrade, and provide the latest processor performance for demanding applications.

Performance Highlights

Test Type	Score of System x3850 X6	Comparison to Previous Record
SPECvirt_sc2013 (benchmark used to measure performance of virtualized platforms)	2,655 @ 147 virtual machines	27% faster
SAP® BW-EML scale-out @ 1 billion records (standard application benchmark SAP Business Warehouse application enhanced mixed load)	1,992,570 nav steps per hour @ 1 billion records	29% faster
SAP BW-EML scale-out @ 10 billion records	269,960 nav steps per hour @ 10 billion records	The first server ever to use 10 billion initial records
ANSYS Fluent x86 R16	Highest performance rate ever for a single x86 server on the fluidized_bed_2m benchmark (ANSYS computational fluid dynamics simulation software for predicting the impact of fluid flows), with a score of 4035.5	19% faster than a similarly configured previous-generation system baselined by Intel (New benchmark; no previous R16 record)

"SAP and Lenovo have been collaborating on early in-memory technologies that resulted in the availability of the SAP HANA platform in 2011. Together, we're providing solutions that range from stand-alone servers to large scale-out clusters that include high availability and disaster recovery capabilities addressing analytics, data mart, and SAP Business Warehouse and SAP Business Suite applications. Lenovo engineers are working closely with SAP HANA developers to optimize these solutions for performance and highest reliability. For SAP HANA, Lenovo delivers the advantage of optimized solutions rather than just servers or components. In addition, Lenovo works closely with technology partners like Samsung and Intel to leverage the potential that new technologies enable in solutions such as SAP HANA. Lenovo is a leader in deployments of SAP HANA, with more than 4,000 installations of SAP HANA, and is committed to delivering continued innovation to address customers' business growth objectives."

Jay Parker, Senior Vice President, PC and Enterprise Business Group, Lenovo

Intel Processor and Memory Bus Technology

Intel's new Haswell-EX Xeon E7 v3 processor represents the third generation of the Intel Xeon E7 CPU family. The Haswell processor features up to 18 cores, up to 45 MB of last-level cache, and support for larger amounts of physical memory.

Thanks to its innovative design with 20% more cores and a large and efficient cache hierarchy, the newest generation of the Intel Xeon E7 CPU family delivers exceptional performance improvements for SAP HANA platform in-memory database processing.

The new Haswell processor architecture also includes the Intel Transactional Synchronization Extensions (TSX) capability, which provides hardware-supported lock elision for improved transactional data processing. This innovative technology boosts the performance of in-memory transactional data processing on systems with high core counts by increasing the scalability of thread synchronization.

SAP HANA is leveraging the Intel TSX capability to improve its existing lock-based programming model, resulting in faster system performance and extended scalability. Another important benefit of the new Haswell processor architecture is the enhanced Advanced Vector Extensions 2 (Intel AVX2) processor instructions. AVX2 expands most integer commands to 256 bits, delivering up to 68% more computing power (GFLOPS) to help solve complex technical problems faster. The performance of SAP HANA platform scan operations, which determine how many items in a database can be scanned per second, has been enhanced to benefit from Intel AVX2.

System Memory: Samsung 64 GB 3DS/TSV RDIMMs at 20 nm class

Samsung is introducing the industry's first 64-gigabyte (GB), double data rate-4 (DDR4), registered dual in-line memory modules (RDIMMs) that use 3DS/TSV package technology. The 3DS/TSV DRAM package includes the DDR4 DRAM dies stacked on top of each other, which are pierced to contain hundreds of fine holes filled with electrodes for vertical interconnect between the DRAM dies. The new RDIMMs include 36 of these 3DS/TSV DDR4 DRAM packages, each of which consists of four stacked 4-gigabit (Gb) DDR4 DRAM dies. The low-power chips are manufactured using Samsung's most advanced 20-nanometer (nm)-class process technology. Samsung 3DS/TSV technology enables multi-die DDR4 stacking to create even higher-density and higher-performance DRAM modules with reduced power consumption. This extends capabilities of computing and analytics in enterprise servers and accelerates expansion of the premium memory market.

For this paper, the 64 GB 3DS/TSV DDR4 solution was benchmarked against the conventional stacked DDR3 DRAM solution of the same DIMM density. This demonstrated superior power efficiency and performance for workloads running in SAP S/4HANA on the Lenovo X6 server platform based on the Intel Haswell-EX processor.

The proof-of-concept database system was a four-way Lenovo System x3850 X6, configured with the components shown in the following table. The operating system was a SUSE Linux Enterprise Server 11 SP3 with the most-recent maintenance kernel.

The proof-of-concept system had been tested with different combinations of CPU and memory DIMMs from Samsung. The idea was to show the impact of using the most-recent DDR4 memory technology compared to DDR3 on the same processor technology (Intel Haswell CPU) for power consumption and performance.

"Data processing and analytics demands are ever-increasing requirements for memory density and energy efficiency. As an industry leader in memory manufacturing, Samsung has been fulfilling these requirements through the introduction of new, cutting-edge memory technologies. TSV stacking is one such state-of-art technology that incredibly enables reduced power consumption while increasing both density and speed. This TSV technology will play a key role in supporting the enterprise and high-performance computing applications, such as SAP HANA, the leading in-memory database platform. Samsung will continue its relentless pursuit to develop memory products yielding the highest density and performance all while reducing power consumption to build a better IT infrastructure for the future."

Dr. Jungbae Lee, Senior Vice President and Head of the Memory Product Planning and Application Engineering Team, Samsung Electronics

Test Environment

To complement the results, we also considered extending the analysis for the previous generation of Intel Xeon CPUs, code-named IvyBridge EX, which only supports DDR3 memory technology. The workloads employed included the following.

Processors	Memory Modules	SAP® Software
Intel Xeon processors E7-8890 v3 @ 2.5 GHz	Samsung 25 nm-class 4 Gb (QDP) 64 GB DDR3 LR DIMM (Part #: M386B8G70DE0-YH9)	SAP HANA® database
Intel Xeon processors E7-8890 v2 @ 2.8 GHz	Samsung 20 nm-class 4 Gb (4H) 64 GB DDR4 3DS/TSV RDIMM (Part #: M393A8G40D40-YH9)	

High-Volume Order-to-Cash Scenario in SAP S/4HANA

The order-to-cash scenario is one of many fundamental business processes that are implemented in enterprise resource planning (ERP) systems such as the one running SAP S/4HANA that we used. This business process covers sell orders being received and processed through customer sales channels, followed by the creation of the delivery request for logistics and shipping. Once the delivery is processed and completed, an invoice is generated and booked.

For this analysis, we simulated with real-world input all steps, from creating multiple orders to processing all above-mentioned steps, and finally creating the invoice in a high-load manner to cover a typical load for midsize to large retail companies.

The testing used two servers: one that hosted the SAP S/4HANA software, and one that hosted the SAP HANA database. The performance and power consumption impact was measured on the database server. The database size was around 1 TB. During the creation of the orders and invoices and the internal processing in the database, stress was put on the memory and CPU subsystem. Therefore, SAP HANA benefited from a scalable memory technology that has good performance-per-watt characteristics and new features in the Intel Xeon processor E7 family.

Low-Level Performance Workload Using Intel MLC

To complement the measurement from the first scenario, we added a low-level performance test to understand how the memory technology affects other types of memory access modes, such as scans and other ratios of read and write.

Intel MLC can measure latency changes with different memory bandwidth usages. Further, the ability to alternate the memory access pattern with an increasing read-write ratio makes it easier to understand low-level performance characteristics that are more typical in analytical scenarios on SAP HANA.

Test Results

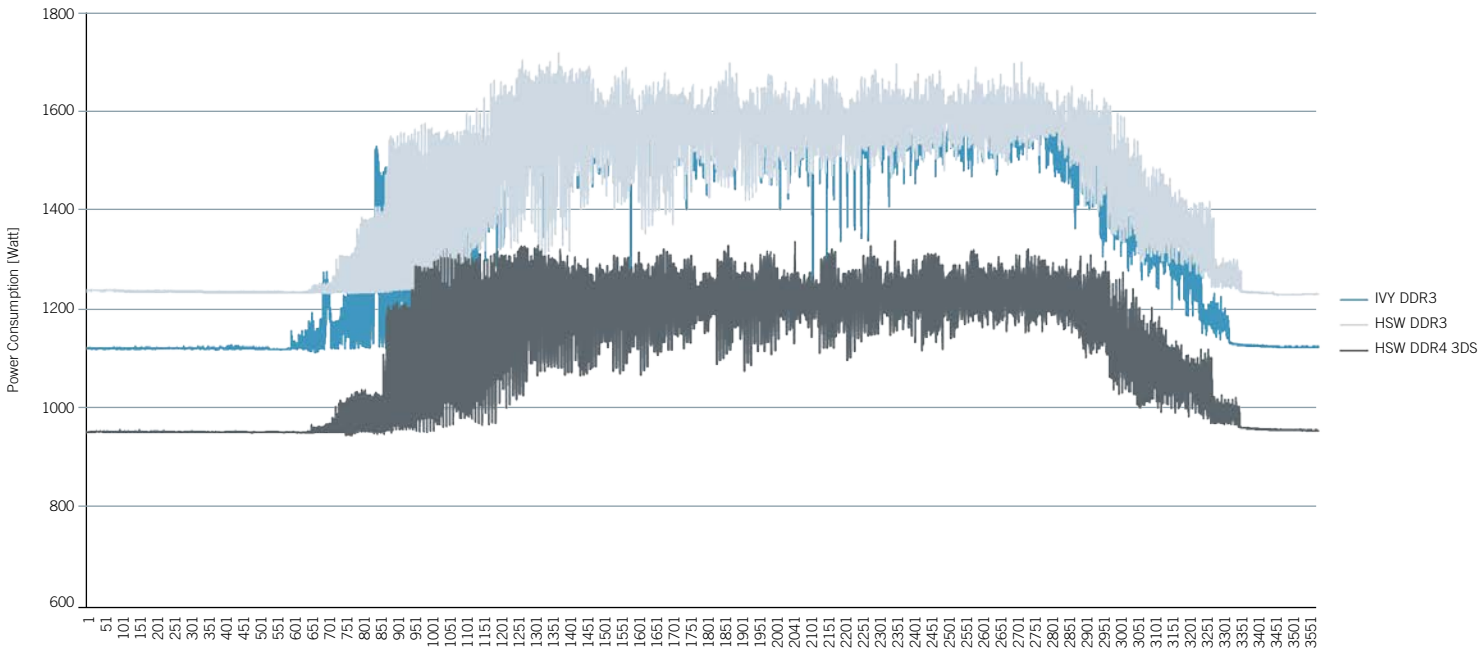
As described above, the testing was conducted using three different configurations:

- IvyBridge-based CPUs with DDR3 technology, which is the current most common configuration
- The new Haswell processors that can be inserted in the same server due to the socket compatibility running with DDR3 memory technology
- The configuration using the new Haswell processors and the new 3DS DDR4 memory technology from Samsung

Before elaborating on the impact of performance per watt with the above-mentioned workloads, we highlighted the average power consumption in idle mode. There was already a significant power reduction using the different DIMMs and CPUs. Comparing the older IvyBridge DDR3 with the newer Haswell DDR3 showed a 4.1% increase of power consumption in idle mode. Figure 1 indicates that CPU and memory have different performance characteristics on idle systems, with the power efficiency benefits of 29.9% using DDR4 compared to the Haswell DDR3. Since not all enterprise systems are in heavy load all the time, we consider this to be very important, as well.

The simulated order-to-cash workload was running with a constant load to make the results comparable. The runtime of the highly concurrent user test was controlled through the simulation tool and was comparable for all runs. During the desired high load, we observed 25 million memory allocations and deallocations per second in the memory manager statistics for SAP HANA. The power consumption curve in Figure 1 clearly shows that the power consumption benefits were also maintained during high load for the 3DS DDR4 64 GB RDIMM modules.

Figure 1. Power profile for order-to-cash workload



With the IvyBridge-based configuration, we were saturating the CPU up to 80% with the chosen workload. The Haswell-based machines were using only half of the CPU resources while being able to serve the same load. The higher resource efficiency of SAP HANA was mainly due to optimization of the Intel Transactional Synchronization Extensions (TSX) for database insert performance. This enabled enough room for going into higher load or to perform analytics on the same system in parallel with less impact on the order-to-cash workload. The observed power consumption benefit was 23.3% comparing DDR4 with Haswell CPUs to the IvyBridge-based CPU with DDR3. The results stayed consistent with multiple iterations of test runs on each configuration.

Finally, we observed an average of 28.6% lower power consumption comparing the newer-generation memory technology based on the 3DS DDR4 64 GB DIMM modules with the DDR3 (see Figure 2).

For the second workload chosen, the Intel MLC test, we modified the BIOS configuration to run the two different memory technologies, DDR3 and 3DS DDR4, with the same frequency (1,333 MHz) on the Intel Haswell processor. The 3DS DDR4 memory technology was able to hold the frequency of 1,600 MHz even with 3 DIMMs per channel; but for a fair performance comparison, we decided to compare the technology with the same frequency. The observed power consumption benefits using the 3DS DDR4 memory was very similar to the previous workload, with an average of around 25% during the bandwidth test. Latency for both memory technologies was exactly the same. However, the bandwidth was higher, with up to an 11% increase for read-only access. The performance increase was even more once we consider adding write access. Figure 3 shows the performance benefits comparing DDR3 LR DIMMs and 3DS DDR4 DIMMs on the Haswell processor. We deduced that using 3DS memory and running them with the same frequency compared to DDR3 LR DIMMs increased

Figure 2. Test results – average power consumption with 3DS DDR4 technology

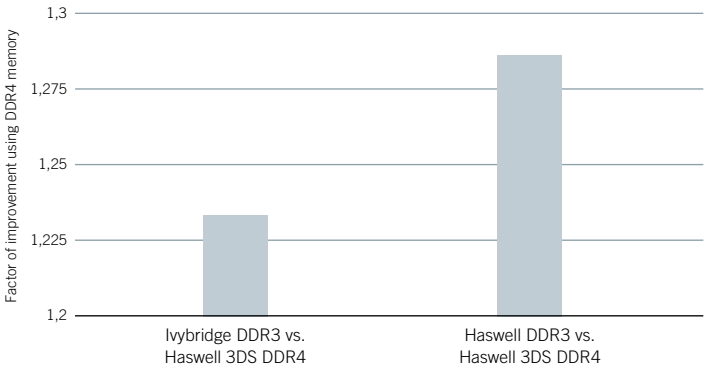
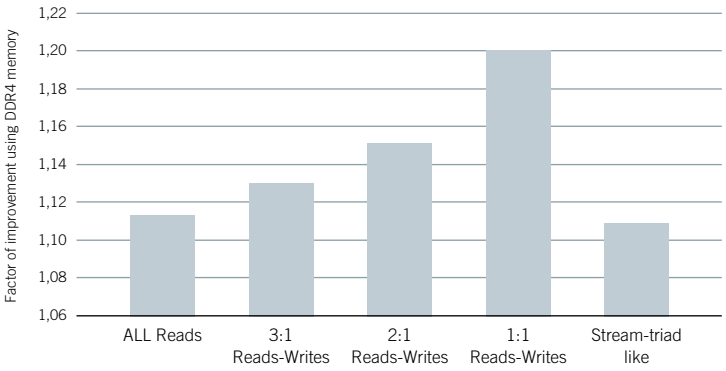


Figure 3. Bandwidth performance improvement with 3DS DDR4 technology using Intel MLC



low-level bandwidth between 11% and 20% depending on the access pattern. And the fact that the performance increase consumed an average of 25% less power highlights that 3DS technology from Samsung has, compared to its predecessor, excellent performance-per-watt characteristics.

Analysis and Conclusions

The test results clearly reconfirmed that Lenovo System x3850/x3950 X6 servers running on Intel's Haswell processor architecture, and the new Samsung 64 GB 3DS/TSV DDR4 RDIMM, are the top choice for high-end enterprise IT platforms such as SAP S/4HANA.

The power savings of the new Samsung DDR4 chips of 28.6% on average on Haswell, compared to a DDR3 chipset, are even more impressive than the 23.3% compared to an IvyBridge platform with DDR3 chipset. (DDR4 is not compatible with IvyBridge.) At the same time, the Haswell architecture allows almost double the data rate and core-to-main-memory ratio for analytical workloads, compared to its predecessor architecture IvyBridge. Plus, the new memory technology enables an increased low-level bandwidth between 11% and 20% across all memory access patterns, with power consumption benefits of around 25% on average. The combination of both technologies provides efficient execution, enabling room for even higher workloads and 3DS memory operation frequency. This allows running analytics and order-to-cash transactions at the same time, for instance, with little measurable impact.

In a nutshell, Samsung 3DS DDR4 on Haswell is the new "dream team" for enterprise IT hardware platforms, and Lenovo brings both innovations together in its x3850/x3950 servers. The new platform enables superior IT performance while significantly reducing power consumption. This not only makes the most of the outstanding performance of SAP S/4HANA. In addition, it brings down the TCO of enterprise IT through reduced energy consumption and decreased cooling efforts, which enables a higher integration of hardware components and further cuts down IT cost.

As a result, everybody is happy. The IT department saves energy and space. The lines of business benefit from more-effective business operations at reduced cost. End users enjoy real-time performance of their business applications. And the organization as a whole reduces carbon footprint while increasing competitiveness.

This clearly demonstrates the leadership and distinguished partnership of SAP, Lenovo, and Samsung as providers of superior IT platforms where software applications and hardware components are perfectly synchronized to match high-end business needs. And all this enables previously unseen innovation and operational efficiency.

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