Quantifying the Power Savings by Upgrading to DDR4 Memory on Lenovo Servers

Demonstrates how clients can significantly save on operational expense by using DDR4 memory

Compares DIMMs currently available on the System x3850 X6 and other Lenovo servers

Shows how DDR4 memory consumes significantly less power than DDR3 RDIMMs and LRDIMMs

Explains that clients should make the transition from DDR3 to DDR4 memory on their Lenovo Intel Xeon-based platforms

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Abstract

This paper quantifies the power savings clients can achieve by upgrading to DDR4 memory on Lenovo servers. It does so by examining the power consumption and performance of different types of DDR3 and DDR4 memory options supported on various Lenovo x86 servers. This paper is for clients who are thinking about the transition from DDR3 to DDR4 based servers.

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Contents

Introduction 3
Comparing 16GB 2Rx4 DDR3 RDIMMs with 16GB 2Rx4 DDR4 RDIMMs 4
Comparing 32GB DDR3 LRDIMMs with 32GB DDR4 RDIMMs 5
Conclusions 8
Related publications and links 9
Author. 9
Notices 10
Trademarks 11

Introduction

This paper demonstrates how the move from DDR3 to DDR4 memory technology reduces power consumption and therefore reduces operational expense in the data center. In order to illustrate the benefits of upgrading to DDR4 based servers, this paper examines the system-level power consumption between different types of DDR3 and DDR4 DIMMs.

Specifically, two power consumption experiments were conducted:

- DDR3 16GB 2Rx4 RDIMMs were compared to DDR4 16GB 2Rx4 RDIMMs operating at the same memory speed
- DDR3 32GB 4Rx4 LRDIMMs were compared to DDR4 32GB 2Rx4 RDIMMs

TruDDR4 memory: Lenovo offers TruDDR4 DIMMs for System x servers which are DDR4 DIMMs that are carefully tested and qualified by Lenovo to operate at speeds higher than industry standards. The memory we've tested here are Lenovo TruDDR4 DIMMs, although in this paper, we're simply referring to them as DDR4 DIMMs.

DDR3 low-power memory: The DDR3 memory we're analyzing in this paper are 1.35V DIMMs (DDR3L). Had we been using 1.5V memory instead of 1.35V, the power savings would be even greater.

The first experiment isolates the power consumption savings using the most popular DIMM of choice, the 16GB RDIMM, by keeping the memory speed constant between the DDR3 and DDR4 measurements. The second experiment is targeted at clients who require a larger memory footprint.

Until now, LRDIMMs were used to meet the demands for high memory capacities. However, with DDR4, Lenovo supports 32 GB RDIMMs across many of its x86 platforms. In this case, not only was the power consumption savings measured, but also the performance increase attributed to the faster memory speeds supported by DDR4 DIMMs.

The Intel Memory Latency Checker (MLC) tool and the SPECcpu2006 benchmark were used to generate a load on the memory subsystem. The measurement configuration used is shown in Figure 1.

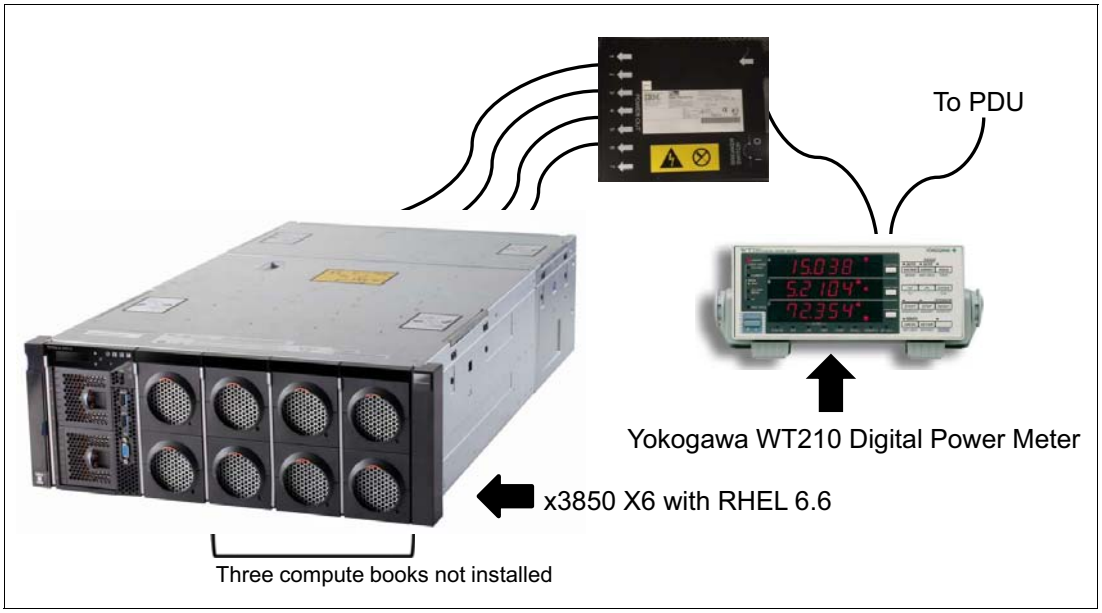

Figure 1 Measurement Configuration

Comparing 16GB 2Rx4 DDR3 RDIMMs with 16GB 2Rx4 DDR4 RDIMMs

The CPU SKU used in this comparison was the Intel Xeon E7-4850 v3 (2.2GHz, 14 cores, 115 W) in a Lenovo System x3850 X6 server. A single processor (single Compute Book) was used for all of the measurement results in this paper, and although a single-socket configuration is not supported for end users for the system used, the results are technically accurate. The memory was configured with two DIMMs per channel (2 DPC) with the following RDIMMs:

- DDR3 memory: 1.35V, 16GB 2Rx4 12800 RDIMMs (part number 46W0672)
- DDR4 memory: 1.20V, 16GB 2Rx4 17000 RDIMMs (part number 46W0796)

DDR4 DIMMs have a lower voltage requirement than DDR3 DIMMs. The Intel Xeon E7 v3 series-based platforms from Lenovo run DDR4 memory at 1.2V, as opposed to DDR3 memory at 1.35V or 1.5V. The lower voltage requirement results in lower power consumption. In addition, DDR4 DIMMs make use of more efficient internal regulators.

Figure 2 on page 5 illustrates the power consumption savings between 1.2V DDR4 and 1.35V DDR3 16GB 2Rx4 RDIMMs over different memory workloads produced by the Intel Memory Latency Checker.

1.5V DIMMs: Although not shown here, the savings are even greater when compared to standard 1.5V DDR3 RDIMMs.

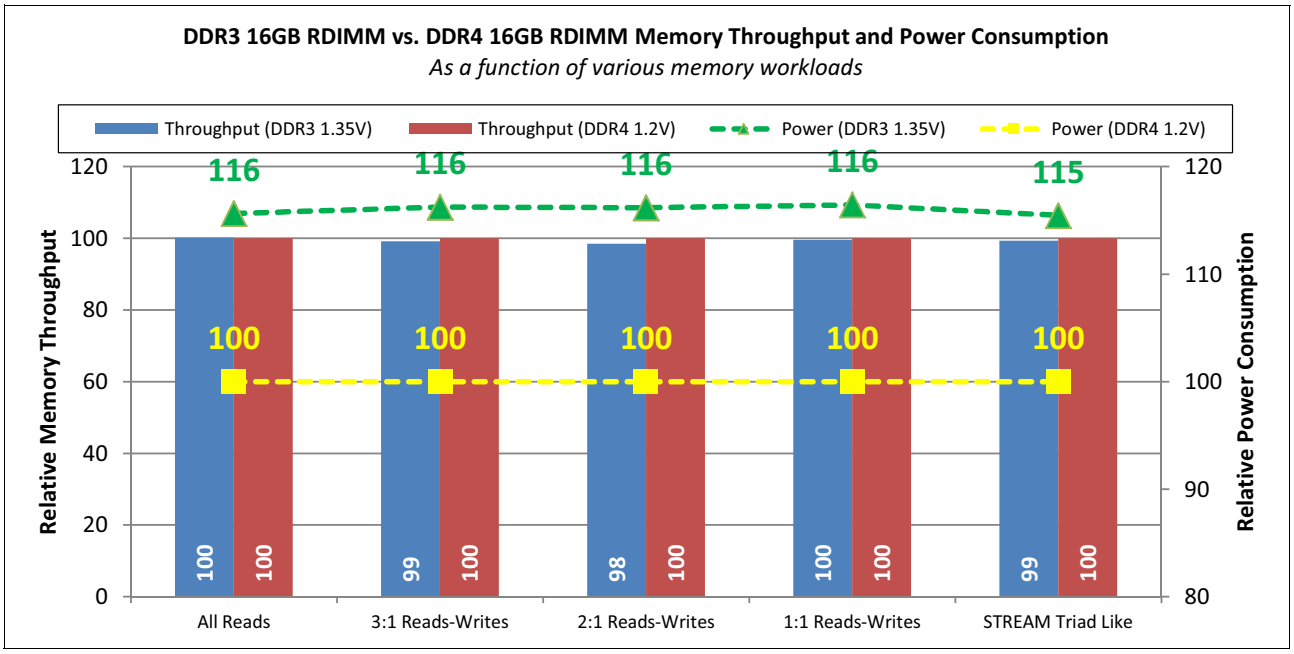

Figure 2 DDR3 16GB RDIMM vs. DDR4 16GB RDIMM Power Consumption

The memory was set to Independent Mode at 1333 MHz memory bus speed for both DDR3 and DDR4. All power saving features were disabled.

The data in Figure 2 was normalized to DDR4 memory at 1333 MHz, which will always reflect 100 percent. When viewing the charts, higher than 100 is better for memory throughput, but worse for power consumption. The vertical bars represent the relative memory throughput between DDR3 and DDR4 across the five different memory workloads, and are associated with the left vertical axis.

As expected, because the memory bus speed and processor are set to equivalent frequencies, the memory throughput is essentially identical for each workload for DDR3 and DDR4.

The square and triangle data markers represent the relative power consumption between DDR3 and DDR4, and are associated with the right vertical axis. Figure 2 clearly shows the DDR3 DIMM power consumption across the five workloads is 15% - 16% more than that of DDR4 memory DIMMs.

Comparing 32GB DDR3 LRDIMMs with 32GB DDR4 RDIMMs

The CPU SKU used in this comparison was the Intel Xeon E7-8890 v3 (2.5GHz, 18 cores, 165 W). The memory was configured with 3 DPC with the following DIMMs:

- DDR3 memory: 1.35V, 3DPC, 32GB 4Rx4 12800 LRDIMMs (part number 46W0676)
- DDR4 memory: 1.20V, 3DPC, 32GB 2Rx4 17000 RDIMMs (part number 95Y4808)

As the previous section indicated, DDR4 DIMMs have a lower voltage requirement than DDR3 DIMMs and have more efficient internal regulators. In addition to those factors, the DDR4 32GB RDIMMs supported on the Lenovo System x3850 X6 use 8 Gb DRAM technology as opposed to the DDR3 32GB LRDIMM which uses 4 Gb technology. As a result, 32GB RDIMMs require fewer DRAM components than 32GB LRDIMMs, which yields

additional power consumption savings. Finally, the LRDIMM has a buffer chip instead of a register found on the RDIMM, and the buffer chip consumes some amount of power as well.

Figure 3 illustrates the power consumption savings for DDR4 32GB RDIMMs versus DDR3 32GB LRDIMMs over different memory workloads produced by the Intel MLC.

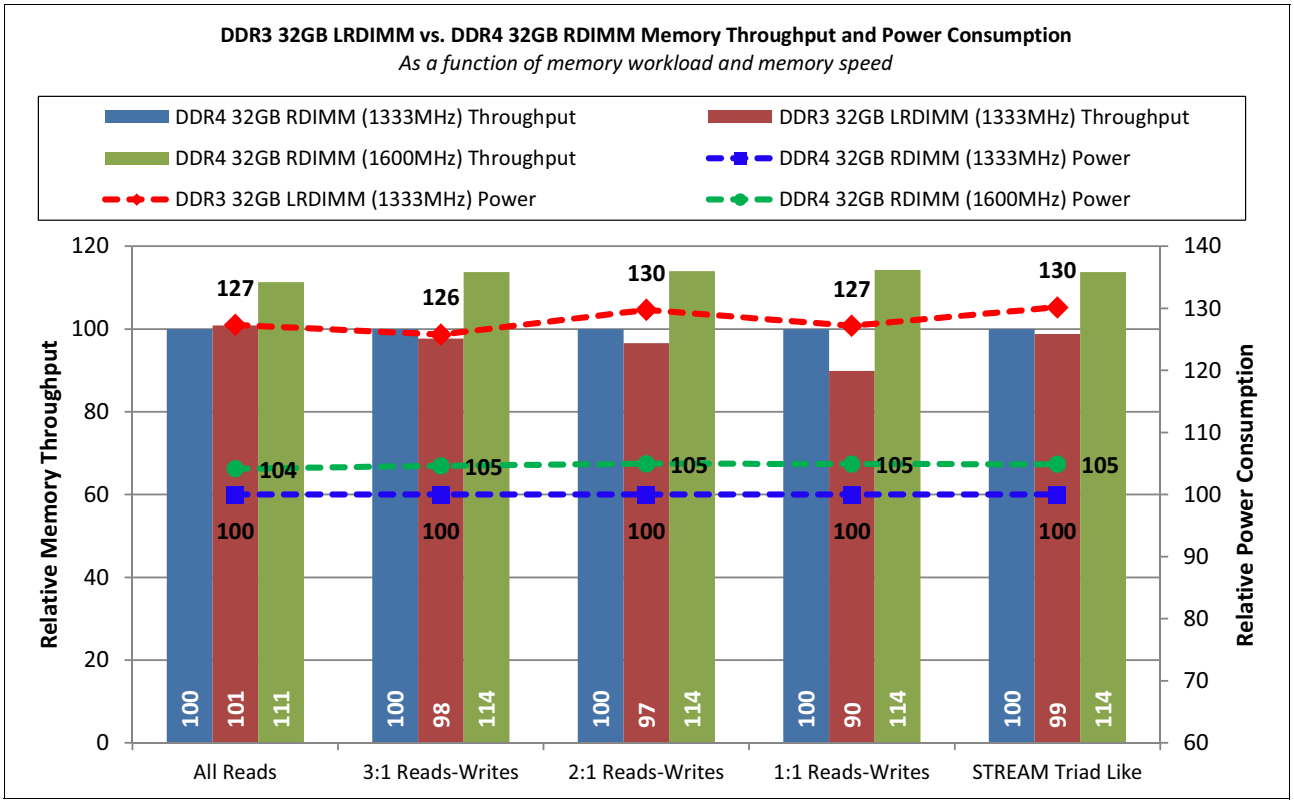

Figure 3 DDR4 32GB RDIMM vs. DDR3 LRDIMM Power Consumption

Again, the memory was set to Independent Mode at 1333 MHz memory bus speed for both DDR3 and DDR4. However, in this case, for the DDR4 memory a second data point was measured at 1600 MHz in Independent Mode. The data was normalized to the DDR4 at 1333 MHz case.

There are several observations that can be made from Figure 3:

- There is not much difference in performance between DDR3 and DDR4 when operating at 1333 MHz. We expect an LRDIMM to have slightly longer latency than an RDIMM at the same memory speed, and that is reflected in the slightly lower performance of the DDR3 LRDIMM across the different memory workloads.
- For the purposes of this paper, the more interesting observation is the difference in power consumption between the LRDIMM and RDIMM at 1333 MHz. The DDR3 LRDIMM consumes 26% - 30% more power than the DDR4 RDIMM. This is due to the lower voltage requirement and the 8 Gb technology of the DDR4 32GB RDIMM.
- Furthermore, increasing the memory speed for the DDR4 RDIMMs to 1600 MHz yields 11% to 14% more performance than the RDIMMs at 1333 MHz across the various memory workloads. However, the increase in power consumption of the RDIMM at 1600 MHz is only about 5% more than the RDIMM at 1333 MHz, and still much less than the LRDIMM power consumption at 1333 MHz.

- Finally, it is more efficient with respect to performance per watt, not only to use DDR4 memory instead of DDR3, but also, to run the DDR4 memory at the faster speed of 1600 MHz. For example, considering the 100% Reads case in Figure 3 on page 6, the relative efficiency of performance per watt is as follows:
  - DDR4 @ 1600 MHz =111/104 = 1.07 (most efficient performance per watt)
  - DDR4 @ 1333 MHz =100/100 = 1.00
  - DDR3 @ 1333 MHz =101/127 = 0.80 (least efficient performance per watt)

Figure 4 illustrates the final power consumption comparison between DDR3 32GB LRDIMMs and DDR4 32GB RDIMMs for the SPECcpu2006 sub-benchmarks hmmer and calculix.

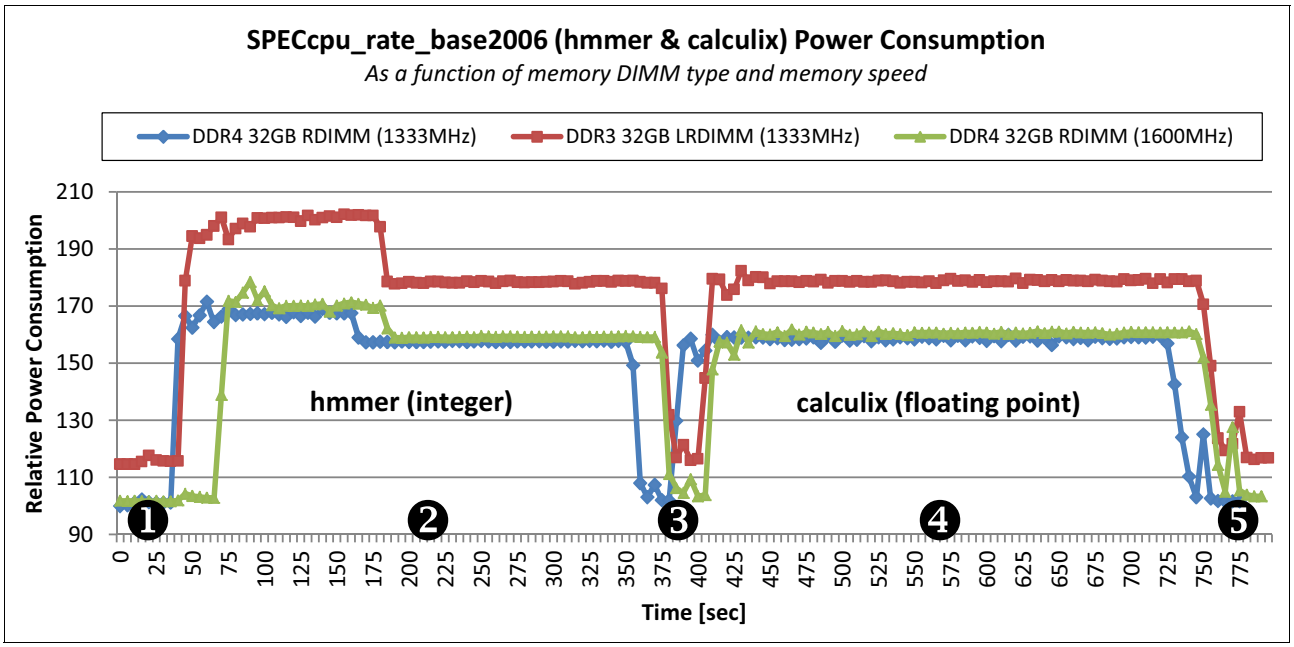

Figure 4 SPECcpu2006 (hmmer and calculix) Power Consumption

SPECcpu2006 is an industry standard application used as an indicator of commercial applications with respect to processor frequency sensitivity (hmmer) and High Performance Computing with respect to more memory bandwidth sensitivity (calculix).

The power consumption data was normalized to the DDR4 32GB RDIMM at 1333MHz. As indicated in Figure 4 the sequence of events is:

1. System at idle
2. Execution of hmmer sub-benchmark
3. System idle between sub-benchmark runs
4. Execution of calculix sub-benchmark
5. System idle

DDR4 RDIMM power consumption at 1600 MHz is only slightly higher than at 1333 MHz, which agrees with the Intel MLC data in Figure 3 on page 6. The power consumption of DDR3 LRDIMMs is up to 20% higher than for DDR4 RDIMMs in the first stage of hmmer, and approximately 13% higher in the second stage of hmmer. The DDR3 LRDIMM power consumption throughout the calculix run is also approximately 13% higher than for DDR4 RDIMMs.

Conclusions

The general observations about power consumption savings in this paper are applicable on any of the following Lenovo Intel Xeon-based servers when comparing DDR3 1.35V/1.5V DIMMs to DDR4 1.2V DIMMs. Such servers include the following:

- Lenovo System x3850 X6
- Lenovo System x3950 X6
- Lenovo System x3650 M5
- Lenovo System x3550 M5
- Lenovo System x3500 M5
- Lenovo ThinkServer® RD650
- Lenovo ThinkServer RD550
- Lenovo ThinkServer RD450
- Lenovo ThinkServer RD350
- Lenovo ThinkServer TD350
- Lenovo Flex System™ x240 M5

Clients with existing Lenovo Intel Xeon E5-2600 v2 or E5-4600 v2-based servers using DDR3 memory can significantly reduce power consumption by upgrading to servers that support the Intel Xeon E5-2600 v3 or E5-4600 v3 series processor and DDR4 memory.

Clients with Lenovo System x3850 X6 or x3950 X6 servers with Intel Xeon E7 v2 processors installed will need to upgrade the compute books to support the E7 v3 processors and DDR4 memory. If the X6 servers already have Intel Xeon E7 v3 processors installed with DDR3 memory they can simply replace the DDR3 memory with DDR4 memory DIMMs.

Furthermore, clients requiring a large memory footprint can transition away from DDR3 32GB LRDIMMs to DDR4 32GB RDIMMs.

The advantages to the client for making this transition are:

- Lower cost point of the DDR4 32GB RDIMM, which will be even lower over time with respect to LRDIMMs
- Significant power consumption reduction with DDR4 32GB RDIMMs
- Better performance per watt efficiency with DDR4 32GB RDIMMs at a higher memory speed than DDR3 LRDIMMs with Intel Xeon E7-8800 v3 series processors

Clients desiring large memory capacity beyond what DDR3 LRDIMMs and DDR4 RDIMMs offer can benefit from DDR4 64GB (and larger) LRDIMMs (up to 12 TB on the x3950 X6, for example).

This paper clearly demonstrates how clients can save on energy consumption and ultimately operational expense, as well as increasing memory performance, by simply transitioning from DDR3 memory to DDR4 memory on their Lenovo Intel Xeon processor-based platforms.

Related publications and links

For more information, consult these references:

- Optimizing Memory Performance of Lenovo Servers Based on Intel Xeon E7 v3 Processors

  https://lenovopress.com/lp0048
- Lenovo System x3850 X6 (6241) Product Guide

  https://lenovopress.com/tips1250
- Lenovo System x3850 X6 and x3950 X6 Planning and Implementation Guide

  https://lenovopress.com/sg248208
- Lenovo System x3850 X6 product page

  http://shop.lenovo.com/us/en/systems/servers/mission-critical/x3850-x6/

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Thanks to the following people for their contributions to this project:

- Randolph Kolvick, STSM & High End Server System Architect
- Robert Wolford, STSM & Power & Efficiency Architect
- Sumanta Bahali, Memory Architecture
- David Watts, Lenovo Press

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