CASE STUDY

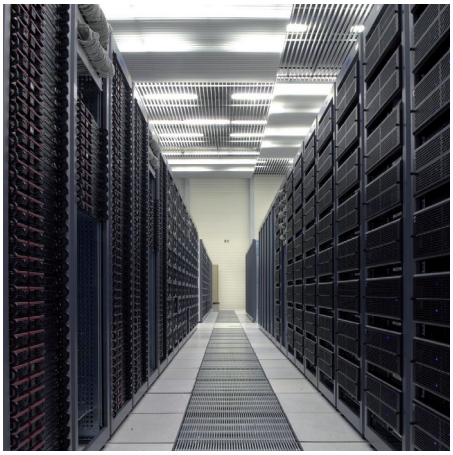
Intel® Xeon® processor 5600 series
Intel® Xeon® processor 7500 series

Performance: Data-Intensive Computing

Defining the future of computing

CERN openlab tests the Intel® Xeon® processor 5600 and Intel® Xeon® processor 7500 series

CERN openlab is a framework for evaluating and integrating cutting-edge IT technologies and services in partnership with industry, focusing on future versions of the World-Wide Large Hadron Collider Computing Grid* (WLCG*). Through close collaboration with leading industrial partners, CERN acquires early access to technology before it is available for the general computing market segment. As such CERN openlab tested an Intel® Xeon® processor 5600 series-based server and an Intel® Xeon® processor 7500 series-based server for use with its Large Hadron Collider* (LHC*) and infrastructure services.



CHALLENGES

- **Test new technologies:** CERN openlab develops and evaluates leading edge IT solutions for CERN in partnership with industry
- **Processor power:** It needs to evaluate the performance, energy-efficiency and scalability of new processors to ensure that CERN has the best technologies available for its Large Hadron Collider (LHC) activities and its infrastructure services

SOLUTIONS

- **Benchmarking next-generation Intel® Xeon® processor:** CERN openlab carried out extensive benchmarking on the Intel® Xeon® processor 5600 series and the Intel® Xeon® processor 7500 series
- **Performance assessments:** Compared next-generation processors to current generation, comparing like-for-like performance and scalability

IMPACT

- **Significant throughput gains:** Intel Xeon processor 5600 series delivered significant overall gains, for example, a 61 per cent throughput increase when using in-house benchmarks[1], compared to the Intel® Xeon® processor 5500 series
- **Stunning performance leap:** Intel Xeon processor 7500 series offered a stunning 3x performance improvement compared to the Intel® Xeon® processor 7400 series
- **Plan and deploy:** CERN ordered 1,500 Intel Xeon processors 5600 series for its activities

"We count heavily on continued improvements in throughput per watt to satisfy the ever-growing demands of the physicists associated with the Large Hadron Collider and its four experiments."

Sverre Jarp, CTO, CERN openlab

Investigating mysteries

CERN is a world-renowned organisation that carries out research in elementary particle physics. Its current focus is on the Large Hadron Collider (LHC), the world's largest and highest-energy particle accelerator, designed and built by CERN to address some of the most fundamental questions of physics. Answers to these questions will advance humanity's understanding of the deepest laws of nature.

The LHC supports four main experiments: ALICE*, ATLAS*, CMS* and LHCb*. ALICE studies a fluid form of matter called quark-gluon plasma that would have existed in the first instants of the universe's life. ATLAS and CMS look for new physics including the origins of mass, clues to the nature of dark matter and hints of extra dimensions. LHCb investigates what happened to missing anti-matter created during the Big Bang.

CERN has multiple departments. Among these are the IT Department hosting CERN openlab, a framework for testing new information technologies. The IT Department provides centralized information technology support. It is split into different groups and one of these, Computing Facilities (CF), operates the CERN Computer Centre. As such, CF is responsible for selecting, acquiring and installing servers.

Intel® Xeon® processor 5600 series delivers compelling performance punch and energy-saving benefits

The CERN Computer Centre is operated as the Tier-0 centre inside CERN's World-Wide LHC Computing Grid* (WLCG). The WLCG is a scientific data grid based on computer centres around the world. It has a four-tier computing model in which data from LHC experiments is collected, stored and distributed to scientists around the world. The CERN Tier-0 centre is the primary back-up for data. After initial processing, the data is distributed to Tier-1 centres that have sufficient storage capacity and can support the Grid around-the-clock. The data is then made available to Tier-2 centres, which can store sufficient data and provide adequate computing power for specific analysis tasks. Individual scientists can access these facilities through Tier-3 computing resources which can be local clusters in a university department or even individual computers.

CERN openlab is a framework for evaluating and integrating cutting-edge IT technologies or services in partnership with industry, focusing on future versions of the WLCG. Through close collaboration with leading industrial partners, CERN acquires early access to technology that is often years from the general computing marketplace. In return, CERN offers expertise and a highly demanding computing environment for pushing new technologies to their limits, which provides a neutral ground for carrying out advanced R&D with various partners.

Testing new processors

CERN openlab has four Competence Centres. One of these centres, the Platform Competence Centre (PCC) is, among other things, dedicated to carrying out tests on relevant Intel processors.

CERN openlab wanted to evaluate the performance, scalability and power consumption of servers based on the Intel® Xeon® processor 5600 series and the Intel® Xeon® processor 7500 series to assess whether these processors might have benefits for, the CERN Computer Centre, and CERN openlab PCC, the IT department and sub-groups within the IT department such as Platform and Engineering Services (PES), whose main mission is the provisioning of services on a large scale to Grid and local CERN users.

CERN openlab tested an Intel Xeon processor 5600 series powered server and an Intel Xeon processor 7500 series powered server. It used the HEPSPEC06 benchmark and other benchmarks derived from physics computing. HEPSPEC06 is a selection of applications from the SPEC* CPU 2006 test suite run under well-defined conditions typical of Worldwide LHC Computing Grid applications.

Benchmarking

In the benchmark the Intel Xeon processor 5600 series, running at 2.93 GHz with a thermal design power (TDP) of 95W, was compared to the Intel® Xeon® processor 5500 series, also running at 2.93 GHz with a TDP of 95W. The Intel Xeon processor 5500 series, however, has four cores (eight threads) compared to the six cores (12 threads) of the Intel Xeon processor 5600 series. A dual-socket system was used.

The Intel Xeon processor 5600 series has 50 per cent more shared L3 cache (reaching 12MB) compared to the Intel Xeon processor 5500 series. CERN openlab noted that the additional two cores and the 4MB bigger L3 cache were added with no penalty in terms of frequency, while keeping power consumption within the thermal envelope. The benchmark test used a 64-bit Scientific Linux* Cern 5.4 (SLC5) based on Red Hat Enterprise Linux* 5 (server).

The motherboard installed in the test system was a Super Micro X8DTN+* motherboard that supports up to 18 DDR3 memory DIMMS clocked at 800, 1066 or 1333 MHz. An Intel® X58 chipset was connected to an ICH10-R chip that manages SATA connectivity. The test system was equipped with 12GB of memory, (6x2) GB DIMMs) and a 500GB SATA hard drive. Some tests were run with an additional 12GB of memory.

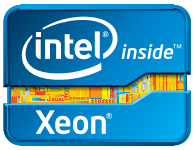
Performance increases

The Intel Xeon processor 5600 series has a 50 per cent core increase compared to the Intel Xeon processor 5500 series. This is reflected in the performance of the monitored applications. The additional two cores, compared to the four cores of the Intel Xeon processor 5500 series, yielded an extra 32 per cent to nearly 50 per cent in performance, depending on the benchmark. Its variant of the SPEC benchmark, HEPSPEC06, provided 32 per cent more throughput. The HEPSPEC performance per watt improved by up to 23 per cent.

The Intel Xeon processor 5600 series showed good scaling from eight to 12 cores, and the result of this is 32 per cent more throughput. This was achieved on HEPSPEC06. There was a throughput increase of up to 61 per cent when using the in-house benchmarks, compared to the Intel Xeon processor 5500 series. This development was noted as being 'quite important' for the CERN Computer Centre.

With regards to energy consumption Sverre Jarp, CTO, CERN openlab, said: "We count heavily on continued improvements in throughput per watt to satisfy the ever-growing demands of the physicists associated with the LHC and its four experiments. CERN considers the platform power consumption an important factor given the power constraints in its computer centre building."

Following those and other benchmarking tests, CERN IT Department decided to purchase servers based on the Intel Xeon processor 5600 series.



More cores, new memory subsystem

CERN openlab benchmarked the Intel Xeon processor 7500 series against the Intel® Xeon® processor 7400 series. The Intel Xeon processor 7500 series has eight cores and a new memory subsystem.

It noted that the Intel Xeon processor 7500 series represented a major change, especially with regard to the memory subsystem. Each processor incorporates the memory controllers that handle all the memory directly attached. This means that in a well-balanced system, each physical processor directly manages half of the server's total memory and accesses the other half indirectly through a request to the other processor.

As a result, CERN openlab decided it was important to make multiple benchmarking comparisons. In most of the benchmarking tests, two four-socket systems were compared – the older one with 24 cores and the more recent (tested) one with 32 cores and 64 threads.

In some cases though, it was important to compare systems that integrated the latest processor features such as Intel® QuickPath Interconnect (Intel® QPI) links, symmetric multi-threading and over-clocking via Turbo mode. In these cases the Intel Xeon processor 7500 series was compared to a dual-socket Intel Xeon processor 5500 series with an identical frequency of 2.26 GHz.

Intel QPI technology replaces the front-side bus (FSB) by offering a point-to-point connection between a CPU and a chipset or between two CPUs. With the Intel Xeon processor 7500 series, four Intel QPI links have been created so all remote memory is available within one hop for such a configuration.

The test system was a QSSC-S4R* server jointly developed by Intel and Quanta. It provided four LGA-1366 sockets to connect up to four Intel Xeon processor 7500 series. Two Intel® 7500 I/O Hubs were also used to handle I/O. Up to 10 PCIe expansion boards were plugged into this 4U server.

Performance jump

CERN openlab noted that the Intel Xeon processor 7500 series provided a significant jump in performance and efficiency compared to the previous Intel Xeon processor 7400 series. It cited the 'architectural jump' as a significant improvement over the Intel® Core™2 processor and the switch from FSB to Intel QPI – a much more scalable bus implementation – to many of the improvements it observed.

The Intel Xeon processor 7500 series represented a 33 per cent core increase over the previous generation and each chip had 8MB more cache, bringing the total amount per chip to 24MB.

When considering the overall frequency-scaled throughput of the whole quad processor system the measured throughput improvement slightly exceeded 3.5 x with the HEPSPEC06 benchmark, including hyper-threading.

Spotlight on CERN openlab

CERN openlab is a framework for evaluating and integrating cutting-edge IT technologies and services in partnership with industry, focusing on future versions of the World-Wide LHC Computing Grid (WLCG).Through close collaboration with leading industrial partners, CERN acquires early access to technology that is still years from general computing market. In return, CERN offers expertise and a highly demanding computing environment for pushing new technologies to their limits while providing a neutral ground for carrying out advanced research and development with various partners.

SPEC Benchmarking

The Standard Performance Evaluation Corporation (SPEC) is a non-profit corporation formed to establish, maintain and endorse a standardized set of relevant benchmarks that can be applied to the newest generation of high-performance computers. SPEC develops benchmark suites and also reviews and publishes submitted results from member organizations and other benchmark licensees.

A High Energy Physics (HEP) working group has demonstrated a good correlation between SPEC results and HEP applications when using a subset of C++ tests from the SPEC CPU2006 benchmark suite running under well-defined conditions. The resulting benchmark was called HEPSPEC06.

As a result, the HEP community, including CERN, has decided to use HEPSPEC06. Because SPEC CPU2006 is readily available, its results can be directly generated by computer manufacturers to evaluate the performance of a system aimed at running HEP applications.

"We make our decisions based on price, power and performance against our benchmarks and throughput per server. The Intel® Xeon® processor 5600 series met the criteria we look for across these areas."

Olof Barring,
head of Facility Planning and Procurement, CERN IT Department

When in-house applications were run, the performance increase was between 47 per cent and 87 per cent. This was with hyper-threading being turned off and on respectively.

In summing up, CERN openlab noted both the Intel Xeon processor 7500 series offered a 'stunning' 3x performance improvement thanks to good scaling with 32 cores and a further gain of up to 26 per cent when enabling simultaneous multi-threading. In-house data analysis and simulation benchmarks showed throughput increases in the range of 11 to 60 per cent. The overall power consumption was quite significant, though CERN openlab did not make a direct power consumption comparison with the Intel Xeon processor 7400 series.

Scaling benefits

Sverre Jarp added: "The large number of cores available through the Intel Xeon processor 7500 series is well suited to run either one very large single application or several virtual machines supporting multiple smaller applications."

Olof Barring, head of Facility Planning and Procurement, CERN IT Department, said: "We make our decisions based on price, power, performance against our benchmarks and throughput per server. The Intel Xeon processor 5600 series met the criteria we look for across these areas. Power consumption is particularly important and the Intel Xeon processor 5600 series showed that it could deliver up to 23 percent HEPSPEC06 per watt improvement compared to the Intel Xeon 5500 series."

Deployment and purchasing

The Intel Xeon processor 5600 series is now being deployed across the CERN Computing Centre. The initial deployment, for CERN IT, is for approximately 850 of these processors powering 600 servers. Three hundred of these servers are single processor disk servers. Another 850 Intel Xeon processors 5600 series have been ordered to provide computing power for the LHC and the four experiments via the Worldwide LHC Computing Grid.

Olof Barring added: "The Intel Xeon 5600 series are definitely strong candidates for our competitive tenders where suppliers are invited to find optimal balance between HEPSPEC06 performance and power consumption. The Intel Xeon processor 5600 series provide features we were looking for and in particular it clearly offers grid computing benefits. We are also interested to see what benefits it provides in terms of cloud computing."

Find a solution that is right for your organisation. Contact your Intel representative or visit the Reference Room at **www.intel.com/references.**

Cloud and Grid computing at CERN

The CERN Computer Centre is operated as the Tier-0 centre inside CERN's Worldwide LHC Computing Grid (WLCG). WLCG is a scientific data grid based on computer centres around the world which provides the resources needed for the four main experiments carried out at the LHC, that is: ALICE, ATLAS, CMS and LHCb.

Currently there are 11 Tier-1 and over 100 Tier-2 centres in WLCG. For many years WLCG collaborated with the EGEE (Enabling Grids for E-Science). EGEE was superset of WLCG allowing other sciences to carry out grid computing as well.

Recently CERN decided to join the Open Data Centre Alliance (ODCA). The ODCA Usage Model Roadmap defines usage model requirements and reference architectures to resolve key IT challenges and fulfill cloud infrastructure needs into the future. This vendor-agnostic roadmap helps guide member planning of future data centre deployments, and relies on open, interoperable, industry-standard solutions.

CERN is helping identify these usage models with a view to helping establish technology standards that can be utilized by public and private organizations seeking to develop cloud-based technologies.

The computing needs of CERN will grow as the LHC accelerator performance increases and the LHC experiments gather data at higher rates. CERN is looking to evolve the Tier-0 of WLCG and profit from cloud-based technologies to expand the total resources available, optimize their usage while reducing the maintenance and operational load.

CERN Platform and Engineering Services group is part of the CERN IT Department. Its main mission is the provisioning of services at a large scale to Grid and local CERN users. The group is very interested in virtualization technologies and cloud computing in order to increase the efficiency of the services. Recently it tested two virtual machines provisioning systems, amongst them OpenNebula, an open source toolkit for cloud computing, to understand scalability issues relating to a cloud infrastructure. These tests were mainly run on CERN Computing Facilities powered by Intel® Xeon® processor 5500 series in the course of 2010.

Dr. Bob Jones, EU Projects Coordinator, CERN IT Department, said: "WLCG is evolving into a cloud for scientific research and the Intel Xeon processor 5600 series will help us expand our capacity to handle LHC data."

[1] Performance tests and ratings are measured using specific computer systems and/or components and reflect the approximate performance of Intel products as measured by those tests. Any difference in system hardware or software design or configuration may affect actual performance. Intel may make changes to specifications, product descriptions and plans at any time, without notice.

Requires an Intel® HT Technology enabled system, check with your PC manufacturer. Performance will vary depending on the specific hardware and software used. Not available on Intel® Core™ i5-750. For more information including details on which processors support HT Technology, visit http://www.intel.com/info/hyperthreading

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