CASE STUDY
Intel® Xeon® processor E5 family
Education
High-Performance Computing

Purdue Accelerates Research with a Supercomputer Based on the Intel® Xeon® Processor E5-2600 Product Family

The system delivers triple the performance and double the density of Purdue's 2008 high-performance computing (HPC) platform

PURDUE UNIVERSITY

"This machine is quite a beast. It gives us fabulous compute capability, but not at the power or cooling or floor space requirements you might have anticipated even 12 months ago."

– Gerry McCartney, Vice President for IT and CIO, Purdue University

New cancer therapies? Pinpoint tornado predictions? Clearer understanding of how greenhouse gases influence global warming? Scientists at Purdue University say they're closer to those accomplishments because of the Intel® Xeon® processor E5 family and a collaboration with Intel, HP, and Mellanox. Incorporating new capabilities such as Intel® Advanced Vector Extensions (Intel® AVX) and PCI Express* (PCIe) 3.0 I/O integration, Purdue's 186.9 teraflops (TF) supercomputer ranks 54th on the November 2011 Top500* list of the world's highest-performing HPC systems and 38th on the Green500* list of the most energy-efficient HPC systems.

CHALLENGE

- **Rising demand for HPC resources.** With computational science playing a larger role in more fields, Purdue's award-winning Community Cluster Program needs more HPC capacity for professors and students.

SOLUTIONS

- **Next-generation processors.** The Purdue system uses 1,296 Intel Xeon processors E5-2670, which provide 70 percent higher average performance than the previous generation with less energy.**
- **Balanced platform.** Purdue chose an HP Cluster Platform 3000 SL6500* that includes 648 server nodes with dual-socket processors, 32 GB of memory per node, and a new Fourteen Data Rate (FDR) InfiniBand* interconnect from Mellanox.

IMPACT

- **Higher performance and throughput.** Purdue technologists say the system gives them three times more performance than their 2008 system and double the throughput.
- **Increased scientific productivity.** Scientists analyze larger data sets and obtain faster results. They can examine problems more deeply, eliminate false leads more quickly, and arrive at clearer answers sooner.
- **Greener data center.** The energy-efficient system consumes average total power of 252 kW and ranks 38th on the Green500 list. Purdue reduces its carbon footprint and saves on power and cooling costs.

Intel® Advanced Vector Extensions in the new processors increase floating-point performance

Heavily Used HPC Clusters

At Purdue University, HPC is essential to fields ranging from agronomy to statistics—and its importance is growing. "Forty percent of our research awards at Purdue now involve some elements of high-performance computing to be provisioned for simulation modeling," says Gerry McCartney, vice president for IT and chief information officer at Purdue. "That's up from about 25 percent five years ago, and it's coming in a period when the overall amount spent on research computing is also increasing fairly dramatically."

To meet the rising demand, Purdue established an innovative Community Cluster Program that lets research teams across the campus pool some of their technology funding and obtain more computing power at a better price. The program's four previous clusters have been well utilized—busy more than 95 percent of the time and used by hundreds of researchers from more than 110 research teams.

The Community Cluster Program increased Purdue's HPC resources more than tenfold between 2006 and 2010 and earned a 2010 Innovators Award from *Campus Technology Magazine*. But demand continued to increase, and some massive codes took more than a month to complete. When the program's leaders started planning their fifth supercomputer, they turned to two vendors who had already demonstrated a strong commitment to Purdue: Intel and HP.

Pushing Back the Frontiers of Science

"If I just want somebody to sell me a big box, I could go to Dave's House of CPUs," McCartney says. "But we want to push back the frontiers of science. We want to play big. We need an ongoing relationship with a corporation that plays big itself and can bring resources to the table to help us do that."

Purdue collaborated with Intel, HP, and Mellanox to create a machine that would use Intel's next-generation processors as soon as they were available. Purdue scientists and technology experts worked with Intel and HP to evaluate the architecture. "We wanted our faculty and researchers to look closely enough to decide, 'Will the new technologies make a difference?'" McCartney recalls. "Our guys were able to come back and say, 'Yes. This is significantly better.'"

The result is a powerful supercomputer that McCartney says provides three times more performance than Purdue's 2008 system while consuming less than half the energy and taking half the floor space. "It's like a new laboratory," he comments. Following campus tradition of naming HPC systems after high-achieving alumni, Purdue is calling the system "Carter." Dennis Carter is a Purdue alum and former Intel director of marketing who originated the "Intel Inside" campaign.

"Intel plays big by its nature," McCartney adds. "They and HP and Mellanox engaged with us full-out to make this machine happen. They put people on the floor with us in a discovery relationship to knock the kinks out. They made themselves available to us. We're very happy with the outcome."

Breakthrough Technologies

In choosing and configuring the new system, Purdue's HPC team wanted leading-edge technologies that would deliver higher performance for a wide range of workloads, scale efficiently, and provide the throughput to keep pace with growing data sets. The team chose the Intel Xeon processor E5-2670 2.6 GHz, which combines Intel's latest microarchitecture with the company's 32 nm process technology. Intel calculations show that the Intel Xeon processor E5 family delivers up to double the floating-point performance as measured by the Linpack* benchmark compared to the Intel Xeon processor 5600 series, and up to 70 percent more performance on real HPC workloads.**

The Intel Xeon processor E5 family also meets the team's requirements for throughput. The system uses next-generation FDR InfiniBand from Mellanox to provide peak data rates of up to 14 Gb per second per lane. In addition, the Intel Xeon processor E5 family is

the world's first line of server CPUs to support full integration with the PCIe 3.0 specification. PCIe 3.0 provides faster data transfers and allows HPC systems to scale performance more efficiently as the systems incorporate more nodes. The Purdue computer runs Red Hat Enterprise Linux* 6.1.

"Intel AVX is the most promising part of the Intel Xeon processor E5 family for us," says Mike Shuey, HPC systems manager at Purdue. "These new instructions provide a demonstrable increase in floating-point performance, nearly doubling the performance on benchmarks such as Linpack. In addition, the PCI I/O integration available on the Intel Xeon processor E5 family (specifically, the PCI Express Generation 3), coupled with the Mellanox FDR InfiniBand, provide a dramatic increase in bandwidth. We're seeing a doubling in per-node throughput compared to Quad Data Rate InfiniBand, and our preliminary results indicate that parallel codes for research projects such as severe weather forecasting and cancer stem-cell detection scale better than we've anticipated."

Faster Time-to-Science

With the Carter supercomputer, Purdue researchers and students enjoy greater access to essential HPC resources and faster turnaround on critical jobs. "We're accelerating our researchers' time-to-science, for both our high-throughput users and our high-performance users," says McCartney. "Some researchers who previously had to go through a national center to get an allocation for their biggest codes will be able to do their science immediately on Carter."

Researchers such as Michael Baldwin, assistant professor of atmospheric science at Purdue, are seeing an immediate impact. Baldwin studies how climate change influences severe weather events. "Our climate models are easily twice as fast now, and they seem to scale much farther than ever before," Dr. Baldwin says. "Run times have gone from two hours to seven minutes."

Looking to the Future

McCartney is already looking to the Community Cluster Program's next HPC system and eyeing advances such Intel® Many Integrated Core (Intel® MIC) architecture. "As soon as a set of services becomes available, researchers' expectations as to what is achievable or should be achievable or should be provided immediately grows to not only match what's available but to exceed what's available," McCartney says. "The march to a greater granularity of the analysis and greater accuracy will continue."

SPOTLIGHT ON PURDUE UNIVERSITY

Purdue University serves more than 30,000 undergraduates and 8,000 graduate students at its main campus in West Lafayette, Indiana. The university has more than 15,000 faculty and staff and budgeted revenues for the 2010-2011 academic year of over USD 1.812 billion. Purdue's academic colleges and schools include Agriculture, Education, Engineering, Health and Human Sciences, Liberal Arts, Management, Pharmacy, Science, Technology, and Veterinary Medicine.

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Meanwhile, says McCartney, "Carter is another essential element in science's step forward as it gains better understanding of how the universe works around us. Each step in the machinery allows us to do better science, and it allows the science to be done more quickly and more accurately. These are important steps forward, whether the researchers are looking for cancer-causing cells, developing nanotechnology, or designing new skin-graft technology and biomedical devices."

The work researchers are doing on the Carter system will pay practical benefits. "The new knowledge that researchers will gain creates new ways of understanding," McCartney adds. "As a land-grant institution, our mission is to turn those things into practical and useful and impactful products and services that make a difference to the people of Indiana and to the people of the United States. Carter is very instrumental in enabling that to happen."

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