Case Study

High-Performance Computing

Quad-Core Intel® Xeon® processors

Quad-Core Intel® Processors Provide a Bigger Bang for Astrophysics Research

The Canadian Institute for Theoretical Astrophysics (CITA) chooses Quad-Core Intel® Xeon® processors to power a new high-performance computing cluster used to investigate the origins of the universe

Challenges

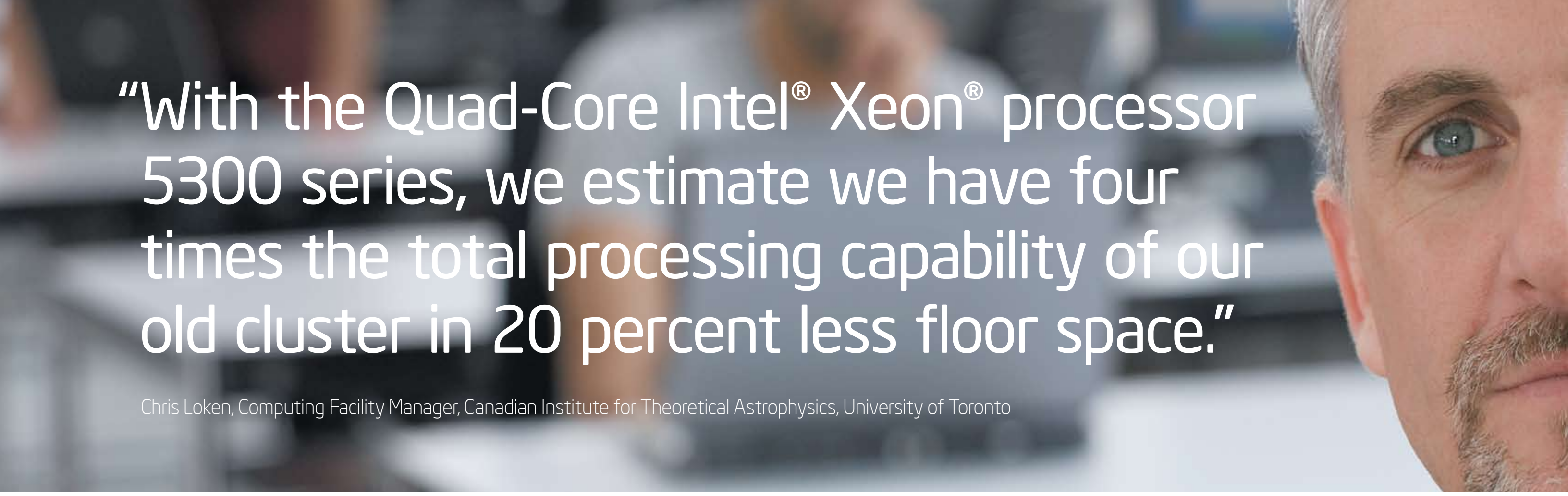
- Increase processing capabilities to keep up with the demands of advanced astrophysics research, including analysis of the "big bang" background radiation
- Make maximum use of the data center space available to CITA at the University of Toronto
- Stay within the stringent power and cooling constraints of the data center facility

Solutions

- **Accelerate performance:** A new cluster based on the Quad-Core Intel® Xeon® processor 5300 series delivers faster processing, with each core performing an estimated 33 percent more floating point operations per second compared to the previous CPUs
- **Save space:** The new Intel Xeon processors provide eight cores per node, delivering four times the density of CITA's previous nodes
- **Enhance efficiency:** Power requirements per core are reduced approximately 60 percent with the new Intel Xeon processors, enabling increased performance within a limited power envelope

As scientists seek to understand our universe, one of the most promising fields of study is analyzing cosmic microwave background radiation—the radiation left over from the "big bang." By studying this radiation from the very early universe, researchers can learn how the galaxies we see today took shape. The Canadian Institute for Theoretical Astrophysics (CITA) at the University of Toronto is one of the world's foremost centers of this research. Using Quad-Core Intel® Xeon® processors for its new high-performance computing (HPC) cluster is enabling CITA to study the universe in far more detail than ever before.

CITA–ICAT



"With the Quad-Core Intel® Xeon® processor 5300 series, we estimate we have four times the total processing capability of our old cluster in 20 percent less floor space."

Chris Loken, Computing Facility Manager, Canadian Institute for Theoretical Astrophysics, University of Toronto

"This is one of the few large HPC clusters in the world that is dedicated solely to astrophysics research. Our new Quad-Core Intel® processors will help keep us at the forefront of those research efforts for several years to come."

Chris Loken
Computing Facility Manager
Canadian Institute for Theoretical Astrophysics
University of Toronto

Assessing the Situation

Specialized telescopes, sent aloft in high-altitude balloons or located on mountain peaks to avoid atmospheric attenuation, are the tools scientists use to gather raw data for cosmic radiation research. Advances in telescope technology are greatly increasing the amount of data collected. "New high-altitude missions are starting now that will gather 1,000 times as much data as before," says Chris Loken, computing facility manager for CITA. "One of these telescopes is projected to generate about 240 gigabytes of data every night for several months. Just keeping up with that volume of data and its analysis requires more and more processing capability."

The growing complexity of today's research also contributes to the need for more powerful processing. "Studying the microwave background radiation in ever-finer detail has been vital to advancing our scientific knowledge," explains Loken. "For example, the temperature signature of the radiation appeared fairly smooth when first studied. But as more detailed analysis became possible, scientists detected temperature variations they now believe helped give rise to structures such as the galaxies."

To accommodate the burgeoning amounts of data and more detailed work required, CITA obtained funding for a new HPC cluster of 200 nodes. The new servers would replace an older cluster located in the University of Toronto's central computing and network services data center, but there were major challenges to overcome. "Our goal was to get as much computing power as we could, subject to two very important conditions," says Loken. "Our physical space could not increase beyond the area vacated by the old cluster, and our net energy use had to remain approximately the same. The data center was full, and was close to being maxed out for power and cooling."

Key Technologies

- Quad-Core Intel® Xeon® processors
- Dell PowerEdge* 1950 servers

Delivering the Solution

The CITA IT organization asked Intel to help come up with a solution. "We've used Intel technology in previous clusters, and we have an excellent relationship with our Intel team," says Loken. "They've been very good about coming out to see us, bringing Intel engineers and consultants with them, and sharing their technology roadmap so we could understand the advances being made. We did look at other processors, but Intel's energy-efficient, quad-core processor was clearly the best way to go."

Loken's team decided to build the new HPC cluster using Dell PowerEdge* 1950 servers with the two-socket, Quad-Core Intel® Xeon® processor 5300 series. The Intel® technology–based servers have enabled CITA to meet the processing demands of advanced research without exceeding the available data center footprint and power envelope.

More Processing Capability in Less Space

The previous HPC cluster used by CITA astrophysics researchers had single-socket, dual-core processors, or two cores per node. The new cluster provides eight cores per node, a fourfold increase. In addition, CITA estimates that each individual core can perform approximately 33 percent more floating point operations per second compared to the old CPUs. As a result, CITA researchers can analyze more data in less time.

"It all adds up to dramatically improved research capacity," says Loken. "With the Quad-Core Intel Xeon processor 5300 series, we estimate we have four times the total processing capability of our old cluster in 20 percent less floor space. Not only can we get more work done, we now have enough headroom to take us through the next five years."

Spotlight: CITA

The Canadian Institute for Theoretical Astrophysics (CITA) is a nationally supported research center for studies in theoretical astronomy hosted by the University of Toronto. CITA receives research support from the National Science and Engineering Research Council and the Canadian Institute for Advanced Research. CITA's primary missions are to foster interaction within the Canadian theoretical astrophysics community and to serve as an international center of excellence for astrophysics study.

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Keeping Power and Cooling Requirements Down

As part of the move to new processors, the CITA team greatly improved the energy efficiency of the HPC cluster. "Our old cluster drew about 110 watts per core according to our measurements," Loken says. "With the Quad-Core Intel Xeon processors, we're down to a little over 40 watts per core. That's an improvement of about 60 percent, which enabled us to put more CPUs in a very power-constrained environment."

Due to the efficiency of the Intel® processors, the 400 percent increase CITA achieved in core density resulted in only a 20 percent increase in power requirements. The IT team offset that 20 percent by eliminating unnecessary power usage elsewhere in the data center. "We also stayed within the cooling limitations of the facility," Loken says. "Since the new Intel processors are more energy efficient, they reduce server power draw and the resulting system heat."

Enabling More Advanced Research

The new Intel® technology–based cluster came online just in time to help analyze data from a new research telescope, called the Atacama Cosmology Telescope (ACT), which is gathering unprecedented amounts of information about cosmic microwave background radiation. In addition, CITA researchers are using the cluster to run highly complex numerical simulations that allow scientists to study how the universe evolved after the big bang event.

To perform the simulations, researchers begin with data about a portion of the early universe and run a specialized program to simulate how galaxies and other cosmic structures might have developed over millions of years. "The simulation program is based partly on fluid dynamics code and partly on gravitational body dynamics code, both of which require large amounts of computing power to run," Loken explains. "With our new HPC cluster, we're able to take part in this important but very demanding work."

Helping to Attract Top Talent

Loken also believes the cluster is making it easier to attract top post-doctoral fellows and graduate students to the CITA program. "Scientists want to work where the HPC resources are available to help make their projects feasible," Loken says. "We now have over 25 researchers in addition to six full-time faculty members, and I'm sure that knowing about this computational capability was a factor for many of them. This is one of the few large HPC clusters in the world that is dedicated solely to astrophysics research. Our new Quad-Core Intel processors will help keep us at the forefront of those research efforts for several years to come."

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