Linux, Intel and Dell Supercomputing at a Major University

SOLUTION SUMMARY

Challenge	How can a university school of computing provide supercomputer facilities cost-effectively for a fast-expanding and diverse array of research projects, while avoiding the commitment to heavy expenditure on cluster management and maintenance?
Solution	The National University of Singapore's School of Computing commissioned Dell* in partnership with SCS Enterprise Systems Pte Ltd to implement a 128 CPU Linux High Performance Technical Computational Cluster.
Solution Provider	Dell in collaboration with SCS Enterprise Systems Pte Ltd
System Integrator and Installer	SCS Linux Competency Center
Hardware Cluster	64 nodes of dual SMP (symmetrical multiprocessing) Dell PowerEdge* Servers, with a total of 128 CPUs. Each CPU is an Intel® Pentium® III processor 1.4GHz.
Cluster Network	The cluster interconnect comprises a Gigabit Ethernet network for cluster administration and a Myrinet-2000 network for high performance parallel computing tasks.
Software	NPACI ROCKS Cluster OS, which is based on Red Hat Linux 7.2. ROCKS include parallel programming libraries such as MPI, PVM, and various numerical packages such as ATLAS and BLAS. A web-based cluster monitoring tool called GANGLIA from UC Berkley was included.

Business Challenge

The National University of Singapore (NUS) is the island city state's largest university, and the School of Computing is a major resource for educating the professional technologists needed for the increasingly high-tech economy.

The School of Computing has over 100 professors and lecturers. The undergraduate population is 2,000 students and there are additionally over 500 graduate students. The Dell/Intel cluster was purchased to support the teaching of more than ten modules on various aspects of parallel and distributed computing, and to support graduate student's research projects.

Traditional supercomputers are expensive, and this means that access to high-performance processing capacity has to be limited for most research projects. The high cost of traditional supercomputers does not end with the initial capital investment. Maintenance of specialized or none-standard computing platforms requires specially trained engineers and is more expensive.

In recent years, the development of Linux and open source software has made parallel processing and supercomputing possible on Intel-based servers.

The School of Computing was determined to provide the best computing tools to all the research programs that needed them. In order to achieve this, it was necessary to identify a supercomputing architecture that would provide far more processing capacity at a cost ten times lower than previous levels. Ease of use and maintenance would also be major design criteria for the new system.

e-Business Solution

Planning

Dell, together with SCS Enterprise Systems, won the contract to implement a Linux HPC cluster at the School of Computing through a tendering process. SCS Enterprise Systems is a value-added reseller of enterprise systems and a wholly-owned subsidiary of Singapore Computer Systems (SCS). The SCS Linux Competency Center (SCS-LCC) provided the systems integration team for the project.

Linux HPC clusters embody the concept of deploying industry-standard server solutions, such as the Intel-processor based Dell PowerEdge servers, commodity networking equipment and the open source Linux OS to build a high performance computer for parallel processing tasks and computations.

"We are delighted that the School of Computing has now adopted the Linux cluster using Dell servers powered by Intel CPUs, which is widely viewed as the most cost-effective form of supercomputing. We can foresee that this highly scalable form of cluster will fulfill our supercomputing requirements for the foreseeable future, and remove virtually all constraints on system availability for our many research applications."

Professor Teo Yong Meng
National University of Singapore
School of Computing

Linux HPC clusters benefit from Linux and other open source software and often provide a more powerful and less expensive form of supercomputer as compared to proprietary products. Another advantage over proprietary supercomputers is that users' investment in setting up and maintaining Linux clusters is transferable to future systems with similar architecture.

Implementation

The cluster was installed in May 2002. The various hardware elements were delivered to the premises over a period of about one month, for installation in three racks at the School of Computing. Once the components were available, it took three SCS-LCC engineers only about three man days for the cluster to be setup. The Dell-SCS-LCC team has a long track record of successful Linux HPC cluster implementations, and is one of the leading system integrators for such systems.

After the implementation process, the SCS-LCC engineers held a training seminar for the staff of the School of Computing, to teach them how to use and maintain the cluster.

Configuration

The cluster consists of 64 Dell PowerEdge 1550 2-way SMP servers, each with two Intel Pentium III 1.4GHz CPUs, 1GB RAM, 36GB HDD. The LINPACK results for the cluster is 100 GFlops (Giga Floating Point Operations per Second).

The architecture of the supercomputer is configured as a dedicated Linux HPC cluster as shown:

Cluster Network

A Gigabit Ethernet network is used as the cluster interconnect for cluster administration and non-MPI based computing tasks. For high performance MPI-based parallel computations, the Myrinet-2000 network was utilized. The Myrinet-2000 cluster fabric is a high-performance packet-communications and switching technology that is widely used to interconnect HPC clusters.

Features of Myrinet

- Full-duplex 2+2 Gigabit/second data rate links, switch ports, and interface ports, running over fiber media.
- Flow control, error control, and "heartbeat" continuity monitoring on every link.
- Low-latency, cut-through, crossbar switches, with monitoring for high-availability applications.
- Switch networks that can scale to tens of thousands of hosts, and that can also provide alternative communication paths between hosts.
- Host interfaces that execute a control program to interact directly with host processes ("OS bypass") for low-latency communication, and directly with the network to send, receive, and buffer packets.

Access Network

The Cluster is connected to the University's 100 Mbps Ethernet campus LAN, (or Gigabit Ethernet) enabling it to be accessed by students and tutors from any network node.

Software

The cluster operating system used is NPACI (National Partnership for Accelerated Computing Infrastructure) ROCKS from San Diego Supercomputer Center (Cluster and Grid Computing Group) which is based on Red Hat Linux 7.2.

NPACI Rocks is a cluster OS with an integrated cluster management tool and optimized methodology for managing a large Linux cluster.

ROCKS is unique in that it makes complete OS installation on a node the basic cluster management tool. By automating this process, it becomes faster

"The NUS School of Computing Linux cluster has three advantages that other colleges should emulate: NPACI ROCKS has made the Linux cluster easy to manage, Intel and Dell provide the essential server-class reliable building blocks, and SCS-LCC has simplified the operation and maintenance of the project."

Dr Philip Papadopoulos, Ph.D
Program Director for San Diego Supercomputer Center, Grid and Cluster Computing

to reinstall all nodes to a known configuration than it is to determine if nodes were out of synchronization in the first place. This contrasts with configuration management tools that perform exhaustive examination and parity checking of an installed operating system.

ROCKS makes it easy to deploy, manage, upgrade and scale a Linux cluster.

GANGLIA is a web-based monitoring tool from UC Berkley that enables cluster administrators to quickly see all the performance statistics of the cluster at one central node. GANGLIA is included in ROCKS.

Support

The cluster is maintained by the technical staff of the School of Computing, who have been trained by SCS-LCC. SCS-LCC will provide further support should it be required.

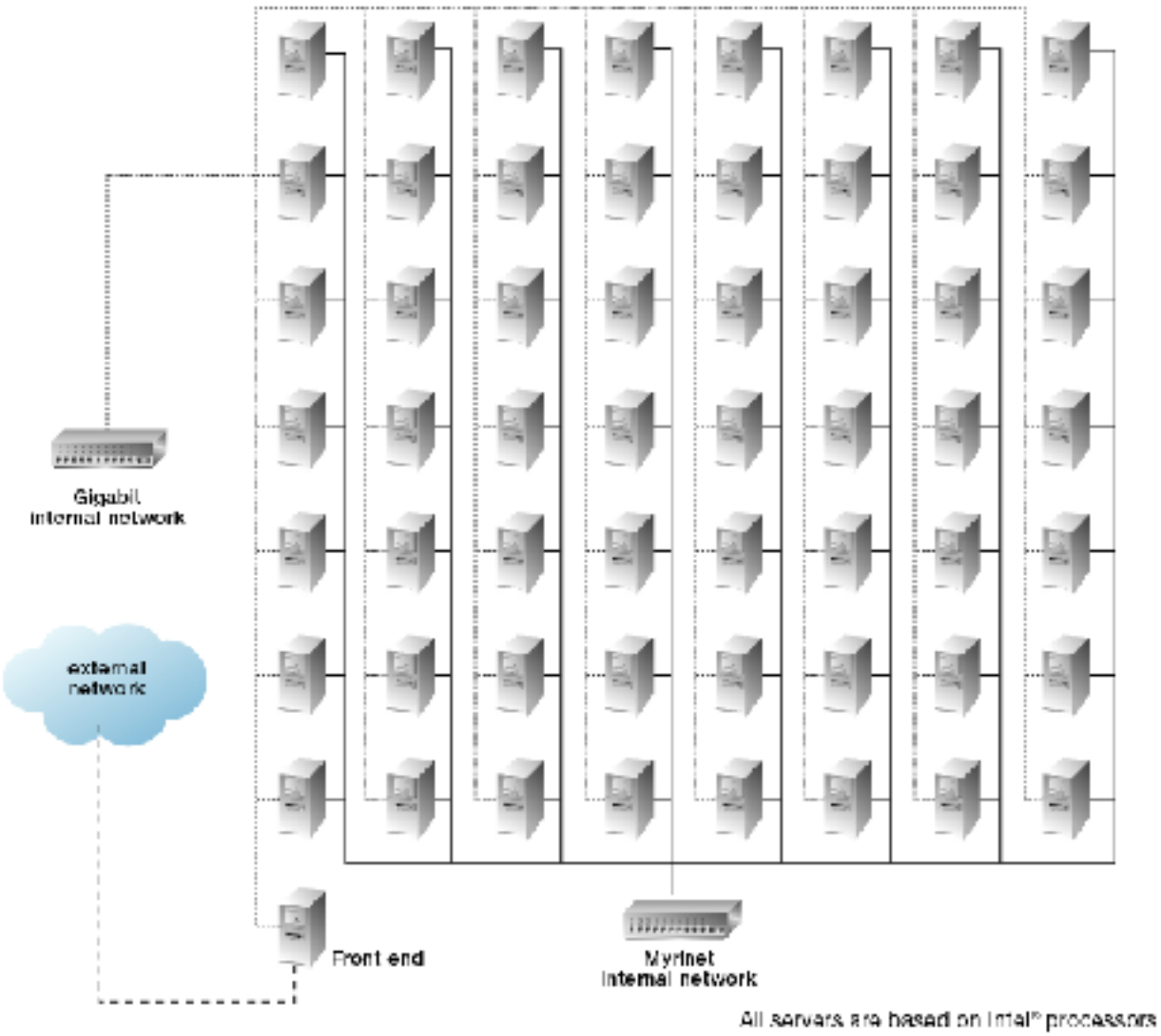
Dell-Intel Server Solution for Linux Clusters

A primary advantage of supercomputers based on clusters of Dell/Intel SMP servers is scalability. "Today, you can buy, say, eight servers, and in six months' time, when demand increases, you can purchase another eight or 16 servers, and plug them in. This incremental and modular scalability of Dell/Intel-based Linux clusters make it very attractive from the financial point of view." said Mr Laurence Liew, Manager, SCS Linux Competency Center.

"Dell was able to provide the smallest footprint, rack-optimized server with the fastest Intel CPU, which was critical to our needs. The Dell-SCC-LCC team has a long track record of implementing clusters in Singapore since 1999, and we are comfortable that their experience with Linux and cluster computing will ensure that our clusters will be integrated correctly and will be able to meet our

System Diagram

National University of Singapore School of Computing
Linux HPC Cluster Network Diagram



technical requirements," said Professor Teo Yong Meng of the School of Computing.

"As cluster computing systems continue to grow in size and capability, companies which run data-intensive applications will choose these systems over traditional supercomputer solutions for their price/performance, scalability and high availability benefits," said Ms Teo Sok Cheng, General Manager of Dell Singapore. "We are honored that NUS and SCS have selected Dell to deploy standards-based systems to support NUS's high-performance Technical Computational Linux Cluster".

Performance Benchmark Attained

An acceptance test based on the parallel processing LINPACK benchmark was performed to show that all of the hardware in the cluster was performing properly. A LINPACK result of 100 GFlops was recorded for the cluster.

Dell/Intel-based Linux clusters typically show a price/performance ratio of at least ten times or better when compared to traditional supercomputers. Linux clusters today can meet the needs of 70% to 80% of most supercomputing tasks, and therefore, this solution is becoming the preferred platform for high performance technical computing today.

Breaking the Cost Barrier

The total cost of the cluster, including all networking equipment, software and services, is approximately S$500,000. A 128 CPU supercomputer costing S$500,000 would have been inconceivable only a few years ago.

In selecting the vendor for the current project, "Price and performance were key," said the School of Computing. Today, the open source community, the Linux OS and the Dell/Intel architecture has provided many researchers with a cost-effective platform for supercomputing. Conventional supercomputers are very expensive, but with the Linux clusters, any university department, or commercial research organization can easily afford a machine with four or eight nodes.

LESSONS LEARNED

- By staying with an open architecture like the Linux operating system and industry-standard Dell-Intel server solutions, the best price/performance in supercomputing are within reach.
- By selecting a system integrator with a deep commitment to state-of-the-art cluster technology, the client can achieve easier implementation and lower the subsequent maintenance overhead.
- Cluster-based supercomputers are now available as an eminently scalable technology, which eliminates the barriers to their use, even for departments or small organizations.
- The use of open systems and standard Intel servers can reduce planning and implementation time from months down to days.
- Every university and technology college will have supercomputing capacity available on its campus network.

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