Building the World’s Largest Linux Supercomputers

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Leading the Cluster Revolution

The Linux Networx TeraFLOPS Club

Lawrence Livermore
11.2 TFLOPS
Linux Networx E2
2,304 Intel Processors

Los Alamos
10 TFLOPS
Linux Networx E2
2,048 Intel Processors

Argonne
1.68 TFLOPS
Linux Networx E2
408 Intel Processors
World’s Most Powerful Linux Supercomputer

- $R_{\text{peak}} = 11.2$ TF, $R_{\text{max}} = 7.634$ TF (68% efficiency)
- # 3 Top 500 Supercomputer List
- # 9 Capability Class Systems (IDC Balanced Ratings)
LLNL System Facts

- 1152 Evolocity II (.8u) Nodes
- 2.4 GHz Intel® Xeon™ Processors
- Quadrics ELAN3 QsNet
- 4.6 TBytes Memory
- 138 TBytes Local Storage
- 115 TBytes Global Storage
Building The System

- Design Prep
  - Rack Layout
  - Cabling Layout
  - Test Plan
- Facility Prep
  - Power Measurements
  - HVAC Estimations
- Built At Factory First
  - Tear Down 3 Days
  - Rebuild at LLNL 3 days
Testing The System

- Test Plan
  - Burn In Full Rack
  - Basic Network Test
  - MPI Stress Test
  - Linpack
  - Pre-Ship Test Suite
  - Post-Ship Test Suite
  - Final Acceptance
Cooling The System

- **Node**
  - Redundant Fans
  - *CPU temp is 24°C Under Heavy Load*

- **Rack**
  - *Patented Cooling Chassis*
  - *18°C In, 22°C Out*

- **System**
  - Hot air flow mix
  - CRAC 80 Tons
Powering The System

- 350 Watts per sq. foot
- Total: 280 kW
- Two 50 amp feeds/rack
- 2 PDUs per rack
- ICE Box Management
  - Power Management
  - Temperature Sensing
  - Serial Console Access
  - Node Beaconing
Reliability

Failures Happen!

- 1000 Components with a 150,000 hour *individual* MTBF have an *aggregate* MTBF of 150 hours if there is no redundancy!
- To combat low *reliability*, applications must checkpoint frequently which degrades *performance*!

Higher Reliability = Higher Performance
MCR (Multi-programmatic Capability Cluster) Architecture

- **Scalable Units**
  - 1 FSU (First Scalable Unit)
  - 11 CNSU (Compute Node Scalable Units)

- **Networks**
  - **MPI** - Quadrics
  - **Management** - Ethernet 10/100
  - **Debug** - Serial
  - **OST** - GigE
  - **Login** - GigE
Scalable Units

- **FSU**
  - 60 Compute Nodes
  - 32 Gateway Nodes (QsNet -> GigE)
  - 2 Login Nodes
  - 2 Management Nodes
  - 2 MDS Nodes (Kimberlite for HA)

- **CNSU** (Compute Node Scalable Units)
  - 96 Compute Nodes Each
MPI Network

- Single-rail Quadrics Elan3
  - 5 usec latency for short messages
  - Got 325 out of 340 MB/sec

- 3:1 Oversubscribed Fat-tree Network
  - 12 first tier, 4 second tier switches
  - Less than 50% degradation (66% expected)
Software Stack

- LinuxBIOS
- Linux
- XFS
- Lustre
- Mpich (Quadrics)
- RMS/SLURM
- Maui/DPCS
- ClusterWorX
LinuxBIOS

- LinuxBIOS on all nodes
- < 2 Seconds from Power-on to Boot Loader
- < 1 Minute from Boot to Login Complete
- Remote Manageability
  - Edit CMOS Parms
  - Flash/store ROM image
- Supports Multi-cast Boot
Lustre

Client

OST

MDS

MDS
Linux NetworX
Accomplishments With MCR

- Fastest Intel or Linux-based system
- Shortest Delivery Time for Top 5 System
- Full System Pre-Stage At Factory
- Remote Imaging
  - 1152 nodes imaged in 15 minutes.
- LinuxBIOS
  - Less than 1 minute Boot
- Highest CPU density - Evolocity II (.8u)
Dr. Still:

“MCR is a great machine. ... Please buy more machines like it.”
High Productivity Computing Systems

Reliability

- Superior patented cooling mechanism
- Redundant bearingless fans
- No component less than 150K hour MTBF
  (Real World = 3 weeks)
- Onsite Buildup

Scalability

- MCR added 192 nodes
High Productivity Computing Systems

Manageability

- HW Management – ICE Box
- SW Management – Clusterworx
- Linux BIOS
- High Density

Performance

- High Performance Linpack / IDC Ratings
Application for Smaller Systems

- Same Components
- Same Cooling Technology
- Same QA/Process
- Full System Pre-Stage At Factory
- Quicker to implement
- Can run smaller systems in ambient temperatures.
- Can add as needs grow.
World’s Fastest Linux Supercomputers