Red Sky
Pushing Toward Petascale with Commodity Systems

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Tuesday March 9, 2010
1. Introduction
2. People
3. Hardware
4. Software
5. Performance
6. Questions?
HPC at Sandia

- Capability Computing
  - Designed for scaling for single large runs
  - Usually proprietary for maximum performance
  - Red Storm is Sandia’s current capability machine

- Capacity Computing
  - Computing for the masses
  - 100s of jobs and 100s of users
  - Extreme reliability required
  - Flexibility for changing workload
  - Thunderbird will be decommissioned this quarter
  - Red Sky is our future capacity computing platform
  - Red Mesa machine for National Renewable Energy Lab
Strategic Goals

- Meet critical and growing need
  - Thunderbird being decommissioned
  - Capacity systems oversubscribed by $4 \times$
  - Set a new standard for value

- Create strategic partnerships
  - Engage tier 1 vendor (Sun/Oracle)
  - Leverage supply chain (Intel)
  - Diversify to energy sector (NREL)

- Sustain leadership
  - Demonstrate feasibility of petascale midrange system
  - Democratize benefits of “Red” architecture
Main Themes

■ Cheaper
  ■ 5× capacity of Tbird at 2/3 the cost
  ■ Substantially cheaper per FLOP than recent capacity platforms

■ Leaner
  ■ Lower operational costs
  ■ Three security environments via modular fabric
  ■ Expandable, upgradable, extensible
  ■ Designed for 6 year life cycle

■ Greener
  ■ 15% less power . . . 1/6 power per flop
  ■ 40% less water . . . 5M gallons saved annually
  ■ Near 10× better cooling efficiency
  ■ 4× denser footprint
Major Innovations

- Bridging from capacity to capability
  - Many “Red” characteristics at commodity price
  - 2-3× faster than Red Storm in mid range
  - 1/3 operational costs

- Top ten Red Sky innovations
  - Petascale midrange system
  - Intel Nehalem processor
  - QDR InfiniBand
  - 3D mesh/torus
  - 12× optical cabling
  - Optical Red/Black switching
  - Refrigerant cooling / glacier doors
  - Power distribution
  - Routing and interconnect resiliency
  - Minimal Ethernet & boot over IB
Floorplan: 68 Blade Racks + 20 Storage Racks

Legend:
- 'Z' x 'Z' raised floor tile
- C48 compute rack with glacier door
- Disk Rack
- APC PDU
- Red/Black switch rack
- Straight-through network connection
- Empty Rack
- Empty space
- Y Dimension IB connections

Section 1 - Always Black
Section 2
Section 3
Section 4 - Always Red

A
S-A1 S-A2
A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12

B
S-B1 S-B2
B1 B2 B3 B4 B5 B6 B7 B8 B9 B10 B11 B12

C
S-C1 S-C2
C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12

D
S-D1 S-D2
D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12

E
S-E1
E1 E2 E3 E4 E5 E6 E7 E8 E9 E10

F
S-F1
F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12

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Capacity Computing at Sandia

Red Sky
(325 TF, 3500 nodes, QDR IB)

TLCC Cluster
(38 TF, 288 Nodes, DDR IB)

IO and Viz clusters

DDN 9550 FC

10GigE Transfer Nodes

2 Login Nodes

Network

12 IB to IB Lustre Routers

2 Login Nodes

IO and Viz

1.5 PB

NAS (200 TB)

HPC 10GigE

NAS/ Mgmt. 1/10GigE

4 Login Nodes

14 IB to 10GigE Lustre Routers

2 Gateway nodes

HPSS
Up to 10 PB

Users

External 1/10GigE

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People

- Integrating an innovative 500+ TFLOP/s system is not easy!
- It requires smart, hard-working people:
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Hardware Overview

- 505 TFLOP/s Peak
- 5,386 nodes (2,693 Sun X6275 blades)
- 2.93 GHz quad core, Nehalem X5570 processors (43,088 total cores)
- 12 GiB DDR3 RAM per node (1.5 per core – 64 TiB total RAM)
- 3D torus InfiniBand
- QDR via Mellanox ConnectX on MB and InfiniScale IV in QNEM
- 1,440 12× IB cables = 9.1 miles (220 miles of optical strands)
- 2,304 1 TB Seagate disks in 96 J4400 JBOD enclosures
  - 2 PB (raw) for /scratch filesystems
- R134a-based cooling doors
- 1.7 MW power
- 1,848 square feet of space in 6 rows
- 68 Sun C48 cabinets
- up to 96 nodes per rack
- up to 768 cores per rack
Power

**Specs**
- High density APC modular PDU: 288 kW in 1/2 rack
- Half rack for six Sun 6048 Racks
- Safely service without forced shutdowns
- 400 A 240Y / 415 V three phase input feed
- $24 \times 3 \times 16$ A 240 V power whips
- Three-to-one reduction in cables
- Delivers far more power per square foot

**Savings**
- Copper – Smaller wire size for 415 V
- Load Power Supply Efficiency
- Less Cooling Required
Cooling

- Sun’s Glacier Door
  - 1st rack-mounted, refrigerant-based, passive cooling system on the market

- Liebert’s XDP
  - First deployment
  - Pumping unit isolates chilled water system from refrigerant circuit
  - Operates above dew point
  - No compressor
  - Power for cooling rather than dehumidification
  - 0.13 kW per kW cooling
Rack: Sun Blade 6048 Chassis

- 4 shelves in a rack
- 12 blade slots per shelf
- 2 nodes per blade slot with X6275
- 1 Chassis Management Module (CMM) per shelf
- 1 QNEM in each shelf
Blade: Sun X6275 (Vayu)

- 2 Nodes per Blade
- Dual-Socket Nehalem-EP Node
  - 2.93 GHz quad-core, 93.8 GFLOP/s peak
  - 3-channel integrated memory controller
  - 1333 MHz DDR3 memory
  - 12 GiB per node
  - 63.9 GB/s peak
- Integrated Ethernet
  - Shared 10/100 mgmt. network
  - 1 Gbit/s Ethernet via NEM (OOB mgmt only)
- Integrated QDR InfiniBand host adapter
  - Mellanox ConnectX
  - 40 Gbit/s to NEM module
QNEM: 3D Torus Building Block

- QDR Network Express Module (QNEM)
- Four in each blade rack (one per shelf)
- Two vertices per shelf, with intra-shelf Z connectivity “on PCB”.
- These switches are interconnected with each other
- No core switches are used
3-Torus Example: 288 36-Port Switch Chip “Nodes”
3-Torus Example: Z Links, No Wrap-Around
3-Torus Example: X Links, No Wrap-Around
3-Torus Example: Y Links, No Wrap-Around
3-Torus Example: Z Wrap-Around Links
3-Torus Example: X Wrap-Around Links
3-Torus Example: Y Wrap-Around Links
3-Torus Example: Host Bristles

Up to 12 host bristles per switch chip
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Software Overview

- CentOS 5.3
- OFED 1.4.2
- SNL modified OpenSM with custom routing engine (torus-2QoS)
- Diskless boot over IB using a custom isolinux bootstrap or gPXE
- oneSIS for shared image and diskless/stateless boot
- git for image management and revision control
- SNL-developed system management toolset
- SNL-developed RAS system
- Linux software RAID
- Lustre 1.8.x with patchless clients
- SLURM + Moab workload manager
- Intel compiler suite
- OpenMPI 1.4.1+
Service Nodes and Who Boots Whom

Management Ethernet

External Network

InfiniBand Network

External Network

34 OSS/MDS

7 Gateway

4 Login

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Integration Challenges

- Naming and attributes
- Red/Black switching, swings, and expansion
- No client Ethernet
- 3D torus on InfiniBand
- No good, resilient routing algorithm for torus
- Some difficulty with $12 \times$ fiber IB cables
- Software RAID for Lustre back-end storage
- Boot over InfiniBand
- New cooling system and impact on operation activities
5 Performance
Linpack

- **Official Top 500 November 2009 #10 result:**
  - 423.9 TFLOP/s on 5,202 nodes
  - 86.9% efficiency

<table>
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<th>N</th>
<th>NB</th>
<th>P</th>
<th>Q</th>
<th>Time</th>
<th>Gflops</th>
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</table>

- \[\|Ax-b\|_oo/(\epsilon*(\|A\|_oo*\|x\|_oo+\|b\|_oo)*N) = 0.0006766 \] ...... PASSED

- **Unofficial #9 result:**
  - 433.5 TFLOP/s on 5,305 nodes
  - 87.2% efficiency

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- \[\|Ax-b\|_oo/(\epsilon*(\|A\|_oo*\|x\|_oo+\|b\|_oo)*N) = 0.0005830 \] ...... PASSED
CTH Shape Charge: Wall Time for 100 time Steps: Weak Scaling with 80x192x80 Cells/core
Mini-Application HPCCG; Weak Scaling:
Wall Times, secs

- Red Storm Quad
- TLCC
- RedSky - NUMA

Wall Time, secs
1 10 100 1000 10000
0 10 20 30 40 50 60 70
PRESTO 4.14.1: Walls Collision (ACME) Weak Scaling
10,240 Elements/task; 596 Time Steps

Wall Clock Time, hr:mi:sec

Number of MPI Tasks

Red Storm Quad
TLCC
RedSky: NUMA
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