ANSYS Fluent 14
Performance Benchmark and Profiling
October 2012
• The following research was performed under the HPC Advisory Council activities
  – Special thanks for: HP, Mellanox
  
• For more information on the supporting vendors solutions please refer to:

• For more information on the application:
  – http://www.ansys.com
- **Computational Fluid Dynamics (CFD) is a computational technology**
  - Enables the study of the dynamics of things that flow
    - By generating numerical solutions to a system of partial differential equations which describe fluid flow
  - Enable better understanding of qualitative and quantitative physical phenomena in the flow which is used to improve engineering design

- **CFD brings together a number of different disciplines**
  - Fluid dynamics, mathematical theory of partial differential systems, computational geometry, numerical analysis, Computer science

- **ANSYS FLUENT is a leading CFD application from ANSYS**
  - Widely used in almost every industry sector and manufactured product
Objectives

• The presented research was done to provide best practices
  – Fluent performance benchmarking
  – Interconnect performance comparisons
  – MPI performance comparison
  – Understanding Fluent communication patterns

• The presented results will demonstrate
  – The scalability of the compute environment to provide nearly linear application scalability
Test Cluster Configuration

- **HP ProLiant SL230s Gen8 4-node “Athena” cluster**
  - Processors: Dual Eight-Core Intel Xeon E5-2680 @ 2.7 GHz
  - Memory: 32GB per node, 1600MHz DDR3 DIMMs
  - OS: RHEL 6 Update 2, OFED 1.5.3-3.10 InfiniBand SW stack

- **Mellanox ConnectX-3 VPI InfiniBand adapters**

- **Mellanox SwitchX SX6036 56Gb/s InfiniBand and 40G/s Ethernet Switch**

- **MPI (Vendor-provided):** Intel MPI 4 U2, Open MPI 1.3.3, Platform MPI 8.1.2

- **Application:** ANSYS Fluent 14.0.0

- **Benchmarks:**
  - Eddy_417k – Reacting Flow with Eddy Dissipation Model (417K elements)
## About HP ProLiant SL230s Gen8

<table>
<thead>
<tr>
<th>Item</th>
<th>SL230 Gen8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processor</td>
<td>Two Intel® Xeon® E5-2600 Series, 4/6/8 Cores,</td>
</tr>
<tr>
<td>Chipset</td>
<td>Intel® Sandy Bridge EP Socket-R</td>
</tr>
<tr>
<td>Memory</td>
<td>(512 GB), 16 sockets, DDR3 up to 1600MHz, ECC</td>
</tr>
<tr>
<td>Max Memory</td>
<td>512 GB</td>
</tr>
<tr>
<td>Internal Storage</td>
<td>Two LFF non-hot plug SAS, SATA bays or Four SFF non-hot plug SAS, SATA, SSD bays, Two Hot Plug SFF Drives (Option)</td>
</tr>
<tr>
<td>Max Internal Storage</td>
<td>8TB</td>
</tr>
<tr>
<td>Networking</td>
<td>Dual port 1GbE NIC/ Single 10G NIC</td>
</tr>
<tr>
<td>I/O Slots</td>
<td>One PCIe Gen3 x16 LP slot 1Gb and 10Gb Ethernet, IB, and FlexFabric options</td>
</tr>
<tr>
<td>Ports</td>
<td>Front: (1) Management, (2) 1GbE, (1) Serial, (1) S.U.V port, (2) PCIe, and Internal Micro SD card &amp; Active Health</td>
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<tr>
<td>Power Supplies</td>
<td>750, 1200W (92% or 94%), high power chassis</td>
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<tr>
<td>Integrated Management</td>
<td>iLO4 hardware-based power capping via SL Advanced Power Manager</td>
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<tr>
<td>Additional Features</td>
<td>Shared Power &amp; Cooling and up to 8 nodes per 4U chassis, single GPU support, Fusion I/O support</td>
</tr>
<tr>
<td>Form Factor</td>
<td>16P/8GPUs/4U chassis</td>
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Fluent Performance – CPU Generations

• Intel E5-2680 (Sandy Bridge) cluster outperforms prior generations
  – Performs 46% better than X5670 “Plutus” cluster nodes

• System components used:
  – Athena: 2-socket Intel E5-2680 @ 2.7GHz, 1600MHz DIMMs, FDR IB
  – Plutus: 2-socket Intel X5670 @ 2.93GHz, 1333MHz DIMMs, QDR IB

Fluent 14 Benchmark
(首个_417k)

Platform MPI
InfiniBand FDR

Higher is better
InfiniBand FDR is the most efficient inter-node communication for Fluent
- Outperforms 1GbE by 230% at 4 nodes
- Outperforms 40GbE by 80% at 4 nodes
**Fluent Performance – MPI**

- **Platform MPI provides better scalability than Open MPI**
  - Fluent 14 provides Platform MPI as the default MPI option
  - Up to 24% better performance at 4 nodes

- **Default Fluent run script is used for all cases shown**
  - No other optimization flags were added

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**Fluent 14 Benchmark**

*(eddy_417k)*

<table>
<thead>
<tr>
<th>Nodes</th>
<th>Intel MPI</th>
<th>Open MPI</th>
<th>Platform MPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
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<td>3</td>
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<tr>
<td>4</td>
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</tbody>
</table>

*InfiniBand FDR*

*Higher is better*
• **InfiniBand FDR reduces the time needed for communication**
  – InfiniBand FDR frees up more time for computation
  – Ethernet solutions consume from 74% to 86% of time in MPI communications

![Fluent 14 Profiling](image)
- **Fluent 14 Profiling** (eddy_417k, 4 nodes, 1GbE)
  - MPI/User Time Ratio
  - **14%** MPI time, **86%** User time
  - **Higher is better**

![Fluent 14 Profiling](image)
- **Fluent 14 Profiling** (eddy_417k, 4 nodes, 10GbE)
  - MPI/User Time Ratio
  - **26%** MPI time, **74%** User time

![Fluent 14 Profiling](image)
- **Fluent 14 Profiling** (eddy_417k, 4 nodes, InfiniBand FDR)
  - MPI/User Time Ratio
  - **47%** MPI time, **53%** User time

**16 Processes/Node**
Fluent Profiling – # of MPI Calls

- The most used MPI calls is MPI_Iprobe
  - Aside from MPI_Iprobe, MPI_Isend and Irecv are the next most used calls

**Showing All MPI calls**

Fluent Profiling  
(eddy_417k)  
Number of MPI Calls

**Excluding MPI_Iprobe**

Fluent Profiling  
(eddy_417k)  
Number of MPI Calls

Higher is better

16 Processes/Node
Fluent Profiling – MPI Communication Time

- Majority of MPI communication time is spent on MPI_Init
  - MPI_Init(27%), MPI_Recv(28%)

Fluent Profiling
(eddy_417k, 4-node)
% Time Spent of MPI Calls

Fluent Profiling
(eddy_417k)
Time Spent of MPI Calls

MPI Functions

- 1 Node
- 2 Nodes
- 3 Nodes
- 4 Nodes
Fluent Profiling – MPI Message Sizes

- Majority of messages are small messages
  - Messages below 4KB are mostly used

Fluent Profiling (eddy_417k)
MPI Message Sizes

![Message Sizes Chart]

- 1 Node
- 2 Nodes
- 3 Nodes
- 4 Nodes
Fluent Summary

• **HP ProLiant Gen8 servers delivers better performance than its predecessor**
  – ProLiant Gen8 equipped with Intel E5 series processes and InfiniBand FDR
  – Up to 46% higher performance than ProLiant G7 (running Intel Xeon X5670) when compared at 4 nodes

• **InfiniBand FDR is the most efficient inter-node communication for Fluent**
  – Outperforms 1GbE by 230% at 4 nodes
  – Outperforms 10GbE by 80% at 4 nodes

• **Fluent Profiling**
  – Platform MPI performs 24% better than Open MPI, and 16% better than Intel MPI
  – InfiniBand FDR reduces communication time; provides more time for computation
    • InfiniBand FDR consumes 53% of total time, versus 74-86% for Ethernet solutions
  – MPI:
    • Large MPI call volumes for testing non-blocking data transfers (MPI_Iprobe, MPI_Isend, MPI_Irecv)
    • MPI time is spent mostly on MPI_Recv and MPI_Allreduce
    • Messages are concentrated in small messages, from 0B to 4KB
Thank You
HPC Advisory Council