LS-DYNA Performance Benchmark and Profiling on Windows

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The following research was performed under the HPC Advisory Council activities:
- AMD, Dell, Mellanox
- HPC Advisory Council Cluster Center

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For more info please refer to:
- www.microsoft.com/hpc
LS-DYNA

• **LS-DYNA**
  - A general purpose structural and fluid analysis simulation software package capable of simulating complex real world problems
  - Developed by the Livermore Software Technology Corporation (LSTC)

• **LS-DYNA used by**
  - Automobile
  - Aerospace
  - Construction
  - Military
  - Manufacturing
  - Bioengineering
• **LS-DYNA SMP (Shared Memory Processing)**
  – Optimize the power of multiple CPUs within single machine

• **LS-DYNA MPP (Massively Parallel Processing)**
  – The MPP version of LS-DYNA allows to run LS-DYNA solver over High-performance computing cluster
  – Uses message passing (MPI) to obtain parallelism

• **Many companies are switching from SMP to MPP**
  – For cost-effective scaling and performance
Objectives

- The presented research was done to provide best practices
  - LS-DYNA performance benchmarking
  - LS-DYNA scaling with Windows and Linux
  - Power consumption comparison between Windows and Linux
Test Cluster Configuration

- Dell™ PowerEdge™ M605 10-node cluster
- Quad-Core AMD Opteron™ 2389 (“Shanghai”) CPUs
- Mellanox® InfiniBand ConnectX® 20Gb/s (DDR) Mezz card
- Mellanox® InfiniBand DDR Switch Module
- Memory: 8GB memory, DDR2 800MHz per node
- Windows Server 2008 HPC edition, Mellanox WinOF v2.0, MS MPI
- Linux RHEL5U3, OFED1.4, HP-MPI
- Application: LS-DYNA MPP971_S_R4.2.1
- Benchmark Workload
  - Three Vehicle Collision Test simulation
Mellanox InfiniBand Solutions

• **Industry Standard**
  – Hardware, software, cabling, management
  – Design for clustering and storage interconnect

• **Performance**
  – 40Gb/s node-to-node
  – 120Gb/s switch-to-switch
  – 1us application latency
  – Most aggressive roadmap in the industry

• **Reliable with congestion management**

• **Efficient**
  – RDMA and Transport Offload
  – Kernel bypass
  – CPU focuses on application processing

• **Scalable for Petascale computing & beyond**

• **End-to-end quality of service**

• **Virtualization acceleration**

• **I/O consolidation Including storage**

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**The InfiniBand Performance Gap is Increasing**

![Graph showing performance gap](image)

- **InfiniBand Deliveries the Lowest Latency**

- 240Gb/s (12X)
- 120Gb/s
- 80Gb/s (4X)
- 60Gb/s
- 40Gb/s
- 20Gb/s

- Fiber Channel
- Ethernet
Quad-Core AMD Opteron™ Processor

• **Performance**
  – Quad-Core
    • Enhanced CPU IPC
    • 4x 512K L2 cache
    • 6MB L3 Cache
  – Direct Connect Architecture
    • HyperTransport™ Technology
    • Up to 24 GB/s peak per processor
  – Floating Point
    • 128-bit FPU per core
    • 4 FLOPS/clk peak per core
  – Integrated Memory Controller
    • Up to 12.8 GB/s
    • DDR2-800 MHz or DDR2-667 MHz

• **Scalability**
  – 48-bit Physical Addressing

• **Compatibility**
  – Same power/thermal envelopes as 2nd / 3rd generation AMD Opteron™ processor
Dell PowerEdge Servers helping Simplify IT

- **System Structure and Sizing Guidelines**
  - 8-node cluster build with Dell PowerEdge™ M605 blades
  - Servers optimized for High Performance Computing environments
  - Building Block Foundations for best price/performance and performance/watt

- **Dell HPC Solutions**
  - Scalable Architectures for High Performance and Productivity
  - Dell's comprehensive HPC services help manage the lifecycle requirements.
  - Integrated, Tested and Validated Architectures

- **Workload Modeling**
  - Optimized System Size, Configuration and Workloads
  - Test-bed Benchmarks
  - ISV Applications Characterization
  - Best Practices & Usage Analysis
Dell PowerEdge™ Server Advantage

- Dell™ PowerEdge™ servers incorporate AMD Opteron™ and Mellanox ConnectX InfiniBand to provide leading edge performance and reliability
- Building Block Foundations for best price/performance and performance/watt
- Investment protection and energy efficient
- Longer term server investment value
- Faster DDR2-800 memory
- Enhanced AMD PowerNow!
- Independent Dynamic Core Technology
- AMD CoolCore™ and Smart Fetch Technology
- Mellanox InfiniBand end-to-end for highest networking performance
**Current Issues**
- HPC and IT data centers merging: isolated cluster management
- Developers can’t easily program for parallelism
- Users don’t have broad access to the increase in processing cores and data

**How can Microsoft help?**
- Well positioned to mainstream integration of application parallelism
- Have already begun to enable parallelism broadly to the developer community
- Can expand the value of HPC by integrating productivity and management tools

**Microsoft Investments in HPC**
- Comprehensive software portfolio: Client, Server, Management, Development, and Collaboration
- Dedicated teams focused on Cluster Computing
- Unified Parallel development through the Parallel Computing Initiative
- Partnerships with the Technical Computing Institutes
NetworkDirect
A new RDMA networking interface built for speed and stability

- **Priorities**
  - Comparable with hardware-optimized MPI stacks
    - Focus on **MPI-Only Solution for version 2**
  - Verbs-based design for close fit with native, high-perf networking interfaces
  - Coordinated w/ Win Networking team’s long-term plans

- **Implementation**
  - MS-MPIv2 capable of 4 networking paths:
    - Shared Memory between processors on a motherboard
    - TCP/IP Stack (“normal” Ethernet)
    - Winsock Direct (and SDP) for sockets-based RDMA
    - New RDMA networking interface
  - HPC team partners with networking IHVs to develop/distribute drivers for this new interface
LS-DYNA Performance Results - Linux

- InfiniBand 20Gb/s vs 10GigE vs GigE, 24-node system
- InfiniBand 20Gb/s (DDR) outperforms 10GigE and GigE in all test cases
  - Reducing run time by up to 25% versus 10GigE and 50% vs GigE
- Performance loss shown beyond 16 nodes with 10GigE and GigE
- InfiniBand 20Gb/s maintain scalability with cluster size

LS-DYNA - Three-Car Crash

Lower is better
LS-DYNA Performance – Linux vs Windows

- The testing were limited to 10-nodes system at the given time
- Windows delivers comparable performance to Linux
- InfiniBand enables high scalability for both systems

LS-DYNA Benchmark Result
(Three-Car Crash)

<table>
<thead>
<tr>
<th>Number of Nodes</th>
<th>Elapsed Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 (16 Cores)</td>
<td>11000</td>
</tr>
<tr>
<td>4 (32 Cores)</td>
<td>9500</td>
</tr>
<tr>
<td>6 (48 Cores)</td>
<td>6500</td>
</tr>
<tr>
<td>8 (64 Cores)</td>
<td>5000</td>
</tr>
<tr>
<td>10 (80 Cores)</td>
<td>3500</td>
</tr>
</tbody>
</table>

Lower is better

Windows
Linux
InfiniBand DDR
Power Cost Savings

- Dell economical integration of AMD CPUs and Mellanox InfiniBand saves up to 25% in power
  - 10-node system comparison
    - In the 24-node system configuration, power saving was up to 50% as shown in previous publications
    - Versus using Gigabit Ethernet as the connectivity solutions
    - As cluster size increases, more power can be saved
- Windows and Linux consumes similar power with InfiniBand

$/KWh = Kwh * $0.20
Conclusions

- **LS-DYNA is widely used to simulate many real-world problems**
  - Automotive crash-testing and finite-element simulations
  - Developed by Livermore Software Technology Corporation (LSTC)

- **LS-DYNA performance and productivity relies on**
  - Scalable HPC systems and interconnect solutions
  - Low latency and high throughput interconnect technology
  - NUMA aware application for fast access to local memory

- **LS-DYNA Performance shows**
  - Windows and Linux provide comparable performance figures
  - InfiniBand enables high scalability for both windows and Linux

- **System power consumption**
  - InfiniBand enables big power saving compared to GigE
  - Windows and Linux has same level of power consumption
Thank You
HPC Advisory Council