System Design of Kepler Based HPC Solutions

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Introduction

The System Level View
K20 GPU is a powerful parallel processor!

- **K20 has high raw compute power!**
  - 6.3 – 6.5 X CPUs (Theoretical Peak)

- **Compare to M2090**
  - Kepler (GK110) architecture
  - Transistors 7.1B 2.4X
  - Cores 2496 4.8X
  - Memory 5GB 0.8X
  - Mem-BW 208GB/s 1.17X
  - Power 225W 0.9X
  - SP 3.52 TFLOPs (2.7X)
  - DP 1.17 TFLOPs (1.7X)

- **Challenge:**
  - How to “Realize” & “Extract” maximum performance?
K20 GPU is a powerful parallel processor! Yes, how to get the most out of it?

- “Performance Chain”
- “Balance”
  - Eliminate bottle necks
- Maximize Return from Investment
Some Key Issues: System Level Design

- Number of GPUs per Node
- Dedicated GPU nodes?
- GPUs per node
- Local memory/storage
- Power Budget per Rack
- Number of Nodes with GPUs for best ROI
Servers
Two Server Form Factor Options Ready for K20 GPUs

• PowerEdge C8220X
  – “Shared Infrastructure”
  – 4U
  – Higher GPU & CPU Density
  – Higher Configurability

• PowerEdge R720
  – “Conventional Rack Server”
  – 2U
  – Higher memory per node (768GB)
  – Higher storage per node (24TB)
The C8000 Series: CPU, CPU+GPU Sleds

Based on the “Shared Infrastructure” design

- C8220 (single wide, compute sled)
- C8220X (double wide, compute sled)
- C8220XD (double wide, storage sled)

As demands change it can be reconfigured or scaled out extending the life and value of IT infrastructure investments
Server Details: PowerEdge C8220X

Each C8220X has:

• Up to 2 K20 GPUs
• Two E5-2600 CPUs
• 256GB of memory
• Combine sleds
  – 4 C8220X Sleds in one C8000
• 8 GPUs in 4U space
  – 2 GPU/U Density
Server Details: PowerEdge R720

Each PE R720 has:

- Up to 2 K20 GPUs
- Two E5-2600 CPUs
- 768GB of memory
  - 24 X 32G DIMM
- 24TB local storage
  - 16 X 2.5TB Drives
- 2 GPUs in 2U
  - 1 GPU/U density
Solutions
“Dell HPC Solutions” Mean “Value”

• Solutions “Goal” is to provide “value”
  – Enables you to focus on your “science”
  – Brings your HW up to speed *FAST*

• Engineering Rigor
  – Performance Envelop
  – Measure Total Power Consumption,
  – Expected Power efficiency

• Best practices
  – HPC Advisor
  – Whitepaper Publications,
  – Public Results
“Dell Solutions” Means “Value”
Big part of it the Engineering

• Tests suite includes
  – Node level Performance
  – Cluster level Performance

• Power
  – Total Measured System Power Consumption
  – Performance/watt studies for efficient configurations

• System level
  – Host-to-device, Device-to-host, Device-to-Device
  – Memory subsystem

• Applications level : Benchmarks and Applications
  – HPL, NAMD, NPB, ANSYS
Server Performance & Sensitivity to K20 parameters
## System Configuration: K20 on C8220X and R720 (change of 225W)

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Server</td>
<td>PowerEdge C8220X</td>
</tr>
<tr>
<td>Processor</td>
<td>Dual Intel Xeon E5-2670 @ 2.6GHz</td>
</tr>
<tr>
<td>Memory</td>
<td>128GB @ 1600MHz</td>
</tr>
<tr>
<td>InfiniBand</td>
<td>Mellanox Connect-X 3 FDR</td>
</tr>
<tr>
<td>GPU</td>
<td>NVIDIA Tesla K20</td>
</tr>
<tr>
<td>Rated GPU Power</td>
<td>225W</td>
</tr>
<tr>
<td>CUDA Version</td>
<td>5.0 (304.51)</td>
</tr>
<tr>
<td>OS</td>
<td>RHEL 6.3</td>
</tr>
</tbody>
</table>
K20 is 6.9X the CPUs and faster than double M2090s!

1-node PEC8220X, Dual E5-2670@2.6GHz, 128GB 1600MHz Memory; C8000 has 1 C8220X sled, CUDA 5.0.24 (304.54)
Changing “Power limit” and “GPU Clock Speed”

• On a K20, power consumption and clock rate can be adjusted:
  – `nvidia-smi -ac --application-clocks=<memory, graphics>`
  – `nvidia-smi -pl --power-limit=<limit>`
C8000+C8220X: Single Node Performance Sensitivity to GPU clock

HPL Performance is linearly with GPU Clock Speed

1-node PEC8220X, Dual E5-2670@2.6GHz, 128GB 1600MHz Memory; C8000 has 1 C8220X sled, CUDA 5.0.24 (304.54)
HPL Performance does not degrade at 200W! **save 36.4 Watts**

1-node PEC8220X, Dual E5-2670@2.6GHz, 128GB 1600MHz Memory; C8000 has 1 C8220X sled, CUDA 5.0.24 (304.54)
Changing Power limit and Clock rate

- Performance is more sensitive to “power limit” than “clock”
- Useful for Power Budget limited Cluster design
- Overclock does improve performance but only slightly.
- Useful for “Power Aware” GPU based HPC solution design.
Cluster Performance & Scalability
Cluster Performance

- Performance **Scalability**
  - Number of nodes
  - Number of GPUs

- Total Solution Power **Measured**

- Standard **un-tuned** benchmarks
  - HPL, NAMD, NPB
On average, acceleration is about 7X for less than 2X power compared to CPUs

1-node PEC8220X, Dual E5-2670@2.6GHz, 128GB 1600MHz Memory; C8000 has 1 C8220X sled, CUDA 5.0.24 (304.54)
C8000+C8220X: Scalability
NAMD Perf. & Power (K20 vs. CPU)

On average, acceleration is more than 4X for less than 1.4X power compared to CPUs

1-node PEC8220X, Dual E5-2670@2.6GHz, 128GB 1600MHz Memory; C8000 has 1 C8220X sled, CUDA 5.0.24 (304.54)
How many GPUs?
**NVIDIA** has a tool to answer the question.

- Current Customers may be running GPU enabled apps on CPU only systems.

- New Customers help maximizing return on investment.

- Inputs
  - Fixed Budget
  - Should I buy
    - CPU-only node
    - CPU+GPU node
  - Maximize throughput
    - Future change in application mix
    - Power Savings due to GPUs
How many GPUs?
NVIDIA has tool to answer the question

Outputs: Given a Budget & “Application Mix” Maximize the throughput
Resources

- Blogs
- Whitepapers
- HPC Advisor Online

- www.dell.com/gpu
- www.dell.com/hpc
- www.hpcatdell.com
- www.DellHPCSolutions.com
Resources: www.dell.com/gpu

- Overview
- Supported GPUs
- GPU Specs
- GPU Solutions

GPU accelerators and coprocessors for PowerEdge servers

Hundreds of cores for incredible performance. Add graphics processing units to your PowerEdge servers for increased processing power.

GPU accelerators are available for the PowerEdge R720, T320, T420, T620 and C8220x servers and the C410x PCIe expansion chassis.

Increase the performance of your PowerEdge data center.

Extract some of the highest levels of performance from your Dell PowerEdge servers through a general-purpose computation on graphics processing units (GPU) architecture. When you add GPU processing power to the CPU capabilities already available in your PowerEdge servers, you open the door to outstanding performance across hundreds of processing cores.

- GPUs are high-performance, many-core processors that can be used to accelerate a wide range of applications.
- Advanced GPU programming methods and toolkits enable easy integration into your data center.
- GPU processors can be internally installed in standard PCIe slots or connected externally via...
Resources: HPC Advisor - Tool

- Software application that recommends the best fit Dell products and solutions based on customers specific needs
- Available on Dell.com
- Example: The HPC Advisor asks user:
  - OS type?
  - Optimize for performance, power or density
  - Desired sustained or theoretical performance
  - Recommends a solution based on this input.

http://dell.com/hpc
Summary of the Key Features of HPC Solutions

- **Powerful** (1 or 2 GPU/U Density)
- **Adaptable** (workload based configuration)
- **Flexible** (modular components)
- **Scalable** (Multiple building blocks)
- **Efficient** (Compared to equivalent CPU only clusters)

Start Small,
Grow and Adapt your HPC solution based on your needs!
Backup