Summit Architecture Overview

Scott Atchley
Oak Ridge National Laboratory
Summit Training Workshop 2018
Knoxville TN
December 3, 2018

This research used resources of the Oak Ridge Leadership Computing Facility at the Oak Ridge National Laboratory, which is supported by the Office of Science of the U.S. Department of Energy under Contract No. DE-AC05-00OR22725.
ORNL Summit System Overview

**System Performance**

- Peak of 200 Petaflops (FP_{64}) for modeling & simulation
- Peak of 3.3 ExaOps (FP_{16}) for data analytics and artificial intelligence

**The system includes**

- 4,608 nodes
- Dual-port Mellanox EDR InfiniBand network
- 250 PB IBM file system transferring data at 2.5 TB/s

**Each node has**

- 2 IBM POWER9 processors
- 6 NVIDIA Tesla V100 GPUs
- 608 GB of fast memory (96 GB HBM2 + 512 GB DDR4)
- 1.6 TB of NV memory
Summit Contains 27,648 NVIDIA Tesla v100s

Each Tesla v100 GPU has:

- 150+150 GB/s total BW (NVLink v2.0)
- 5,120 CUDA cores (64 on each of 80 SMs)
- 640 Tensor cores (8 on each of 80 SMs)
- 20MB Registers | 16MB Cache | 16GB HBM2 @ 900 GB/s
- 7.5 DP TFLOPS | 15 SP TFLOPS | 120 FP\textsubscript{16} TFLOPS

Tensor cores do mixed precision multiply-add of 4x4

\[
D = \begin{bmatrix}
A_{0,0} & A_{0,1} & A_{0,2} & A_{0,3} \\
A_{1,0} & A_{1,1} & A_{1,2} & A_{1,3} \\
A_{2,0} & A_{2,1} & A_{2,2} & A_{2,3} \\
A_{3,0} & A_{3,1} & A_{3,2} & A_{3,3}
\end{bmatrix}
\begin{bmatrix}
B_{0,0} & B_{0,1} & B_{0,2} & B_{0,3} \\
B_{1,0} & B_{1,1} & B_{1,2} & B_{1,3} \\
B_{2,0} & B_{2,1} & B_{2,2} & B_{2,3} \\
B_{3,0} & B_{3,1} & B_{3,2} & B_{3,3}
\end{bmatrix}
\begin{bmatrix}
C_{0,0} & C_{0,1} & C_{0,2} & C_{0,3} \\
C_{1,0} & C_{1,1} & C_{1,2} & C_{1,3} \\
C_{2,0} & C_{2,1} & C_{2,2} & C_{2,3} \\
C_{3,0} & C_{3,1} & C_{3,2} & C_{3,3}
\end{bmatrix}
\]

\[
D = AB + C
\]

The M&S community must figure how out to better utilize mixed / reduced precisions

Eg: Possible to achieve 4x FP64 peak for 64bit LU on V100 with iterative mixed precision (Dongarra et al.)
Supercomputer Specialization vs ORNL Summit

• As supercomputers got larger and larger, we expected them to be more specialized and limited to just a small number of applications that can exploit their growing scale

• Summit’s architecture seems to have stumbled into a sweet spot that has broad capability across:
  – Traditional HPC modeling and simulation
  – High performance data analytics
  – Artificial Intelligence
Summit Displays Its Balanced Design
Achieves #1 on TOP500, #1 on HPCG, and #1 Green500 (level 3)

- **122 PF HPL**
  - Shows DP performance

- **144 PF in Nov 2018**

- **2.9 PF HPCG**
  - Shows fast data movement

- **13.889 GF/W**
  - Shows energy efficiency

- **14.668 GF/W Nov 2018**
Summit Excels Across Simulation, Analytics, AI

- Data analytics – CoMet bioinformatics application for comparative genomics. Used to find sets of genes that are related to a trait or disease in a population. Exploits cuBLAS and Volta tensor cores to solve this problem 5 orders of magnitude faster than previous state-of-art code.
  - Has achieved 2.36 ExaOps mixed precision (FP_{16}-FP_{32}) on Summit

- Deep Learning – global climate simulations use a half-precision version of the DeepLabv3+ neural network to learn to detecting extreme weather patterns in the output
  - Has achieved a sustained throughput of 1.0 ExaOps (FP_{16}) on Summit

- Nonlinear dynamic low-order unstructured finite-element solver accelerated using mixed precision (FP_{16} thru FP_{64}) and AI generated preconditioner. Answer in FP_{64}
  - Has achieved 25.3 fold speedup on Japan earthquake – city structures simulation

- Half-dozen Early Science codes are reporting >25x speedup on Summit vs Titan
How is Summit Architecture different from Titan?
ORNL’s leadership supercomputer

- Many fewer nodes
- Much more powerful nodes
- Much more memory per node and higher memory bandwidth
- Much higher bandwidth between CPUs and GPUs
- Faster interconnect
- Much larger and faster file system
- 7x more performance for only slightly more power (Summit’s 8.8 MW vs Titan’s 8.2)

### Feature Comparison

<table>
<thead>
<tr>
<th>Feature</th>
<th>Titan</th>
<th>Summit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak FLOPS</td>
<td>27 PF</td>
<td>200 PF</td>
</tr>
<tr>
<td>Max possible Power</td>
<td>9 MW</td>
<td>13 MW</td>
</tr>
<tr>
<td>Number of Nodes</td>
<td>18,688</td>
<td>4,608</td>
</tr>
<tr>
<td>Node performance</td>
<td>1.4 TF</td>
<td>42 TF</td>
</tr>
<tr>
<td>Memory per Node</td>
<td>32 GB DDR3 + 6 GB GDDR5</td>
<td>512 GB DDR4 + 96 GB HBM2</td>
</tr>
<tr>
<td>NV memory per Node</td>
<td>0</td>
<td>1.6 TB</td>
</tr>
<tr>
<td>Total System Memory</td>
<td>0.7 PB</td>
<td>2.8 PB + 7.4 PB NVM</td>
</tr>
<tr>
<td>System Interconnect</td>
<td>Gemini (6.4 GB/s)</td>
<td>Dual Port EDR-IB (25 GB/s)</td>
</tr>
<tr>
<td>Interconnect Topology</td>
<td>3D Torus</td>
<td>Non-blocking Fat Tree</td>
</tr>
<tr>
<td>Bi-Section Bandwidth</td>
<td>15.6 TB/s</td>
<td>115.2 TB/s</td>
</tr>
<tr>
<td>Processors on node</td>
<td>1 AMD Opteron™, 1 NVIDIA Kepler™</td>
<td>2 IBM POWER9™, 6 NVIDIA Volta™</td>
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<tr>
<td>File System</td>
<td>32 PB, 1 TB/s, Lustre®</td>
<td>250 PB, 2.5 TB/s, GPFS™</td>
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Summit Node Schematic

- Coherent memory across entire node
- NVLink v2 fully interconnects three GPUs and one CPU on each side of node
- PCIe Gen 4 connects NVM and NIC
- Single shared NIC with dual EDR ports
Summit Board (1 node) showing the Water Cooling

Power Supplies (2x)
- 2200W
- 200VAC, 277VAC, 400VDC input

NVidia Volta GPU
- 3 per socket
- SXM2 form factor
- 300W
- NVLink 2.0
- Air/Water Cooled

Memory DIMM’s (16x)
- 8 DDR4 16 DIMMs per socket
- 8, 16, 32, 64, 128GB DIMMs

PCIe slot (4x)
- Gen4 PCIe
- 2, x16 HHHL Adapter
- 1, Shared slot
- 1 x8 HHHL Adapter

BMC Card
- IPMI
- 1 Gb Ethernet
- VGA
- 1 USB 3.0

Power 9 Processor (2x)
- 18, 22C water cooled
- 16, 20C air cooled
Questions?

Summit in Annex Bldg

Titan here