TOP500:5: SIERRA

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1 Introduction

SIERRA is the latest in a series of leading-edge Advanced Simulation and Computing (ASC) Program supercomputers and was procured under the CORAL (Collaboration of Oak Ridge, Argonne, and Livermore national laboratories) partnership. Built by IBM in partnership with NVIDIA Corporation and Mellanox Technologies, Sierra is a heterogeneous supercomputer that uses IBM Power9 central processing units (CPUs) and NVIDIA Tesla V100 Tensor Core graphics processing units (GPUs). This heterogeneous architecture takes advantage of the enormous parallelism in the GPUs to accelerate time-to-solution while providing greatly enhanced energy efficiency over previous systems. Sierra is now the 5th-fastest computer in the world according to the November 2022 TOP500 list (https://www.top500.org/lists/top500/2022/06/).

2 Scientific Goal

The system provides computational resources that are essential for nuclear weapon scientists to fulfill the National Nuclear Security Administration's stockpile stewardship mission through simulation in lieu of underground testing. ASC Program scientists and engineers will use Sierra to assess the performance of nuclear weapon systems as well as nuclear weapon science and engineering calculations.

3 Architecture

Sierra is a classified, 125 petaflop, IBM Power Systems AC922 hybrid architecture system comprised of IBM POWER9 nodes with NVIDIA Volta GPUs.

Unclassified Sierra systems are similar, but smaller, and include:
  lassen - a 22.5 petaflop system located on LC's CZ zone.
  rzansel - a 1.5 petaflop system is located on LC's RZ zone.

IBM Power Systems AC922 Server:
  Hybrid architecture using IBM POWER9 processors and NVIDIA Volta GPUs.

IBM POWER9 processors (compute nodes):
  2 per node (dual-socket)
  22 cores/socket; 44 cores per node
  4 SMT threads per core; 176 SMT threads per node
  Clock: due to adaptive power management options, the clock speed can vary depending upon the system load. At LC speeds can vary from approximately 2.3 - 3.8 GHz. LC can also set the clock to a specific speed regardless of workload.

NVIDIA GPUs:
  4 NVIDIA Tesla V100 (Volta) GPUs per compute, login, launch node
  5120 CUDA cores per GPU; 20,480 per node

Memory:

256 GB DDR4 per compute node; 170 GB/s peak bandwidth (per socket)
16 GB HBM2 (High Bandwidth Memory 2) per GPU; 900 GB/s peak bandwidth

NVLINK 2.0:

Interconnect for GPU-GPU and CPU-GPU shared memory
6 links per GPU/CPU with 300 GB/s total bandwidth (bidirectional)

NVRAM:

1.6 TB NVMe PCIe SSD per compute node

Network:

Mellanox 100 Gb/s Enhanced Data Rate (EDR) InfiniBand One dual-port 100 Gb/s EDR Mellanox adapter per node

Parallel File System:

IBM Spectrum Scale (GPFS)

Batch System:

IBM Spectrum LSF

Water (warm) cooled compute nodes

4 Energy Consumption and Carbon Footprint

Sierra's sophisticated architecture enables the machine to register a peak performance of 125 petaflops using only 11 megawatts of electricity. In other words, Sierra is six times faster than Sequoia (see website) but uses only one-third more wattage.

While no report indicating the existing of extra power system of Sierra, we can reasonably estimate that the electricity powering Sierra comes from the grid of California. According to the Wikipedia on "Energy in California", in 2020, 37.1% of electricity in California came from natural gas, 33.1% came from renewables, and 30% was imported (of which about 30% is known as from renewables, the remaining can be assumed as from fossil fuel).

"Life-cycle greenhouse gas emissions of energy sources" estimates that renewable energy sources typically emit about 50g or less of CO_2 emissions per kWh over their lifetime, compared to about 1000 g CO_2/kWh for coal and 475 g CO_2/kWh for natural gas. Then we can estimate the carbon footprint per flop of the performance of Sierra, that is

$$\frac{11\text{MW} \times (37.1\% \times 475\text{g } CO_2/\text{kWh} + 42.04\% \times 50\text{g } CO_2/\text{kWh} + 20.86\% \times 1000\text{g } CO_2/\text{kWh})}{125 \text{ PFlops/s}}$$

$$\approx 1 \times 10^{-14}\text{g } CO_2/\text{Flop}$$