The L-CSC cluster at GSI for lattice QCD - The most power efficient supercomputer in the world in 2014*

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The L-CSC (Lattice Computer for Scientific Computing) is a new compute cluster installed at GSI dedicated to calculations in the field of Quantum Chromo Dynamics (QCD). QCD is the physical theory describing the strong force, one of the four fundamental interactions in physics. In general, QCD is a non linear, non perturbative theory and the only approach to study it from first principles is Lattice QCD (LQCD). Here, space time is discretized on a four-dimensional lattice, allowing numerical evaluation of the theory. LQCD has extreme demands for memory bandwidth in order to produce results in a reasonable time frame.

In recent years, compute capabilities of supercomputers have increased significantly, but power consumption increased as well. Today, electricity costs for supercomputers are in the same order of magnitude as acquisition costs. Hence, there are strong financial and environmental aspects that advise to build supercomputers with better power efficiency.

Due to the demands of LQCD, the development laid particular focus on memory bandwidth and on power efficiency. Modern GPUs, which can work as a coprocessor in today's compute clusters, offer both: high memory bandwidth and great power efficiency. Accordingly, the chosen architecture uses four GPUs per compute node for L-CSC. This puts high emphasis on GPU computations, while the CPU is merely used for data movement. L-CSC consists of 160 compute nodes equipped either with four FirePro S10000 or four FirePro S9150 GPUs. The reason for the two GPUs models is that the S10000 is better for a higher aggregate compute throughput of small and medium lattices. The S9150 achieves a shorter processing time for individual lattices and can manage larger lattices than S10000. This makes L-CSC applicable for Lattice QCD quite flexibly.

The L-QCD application for L-CSC uses OpenCL and is hence vendor-independent. It was already used with great success on the LOEWE-CSC and Sanam clusters. The $\not{D}$ kernel, which is the computational hotspot of the application, uses the available theoretical peak global memory bandwidth to about 75 %. Since Lattice-QCD is memory bound, there is little room for improvements. This result translates to a compute performance of about 135 GFLOPS on a single S9150 GPU. With four such GPUs, an L-CSC node is more than 10 times faster than a LOEWE-CSC node, which achieves only around 50 GFLOPS. On top of that, with 16 GB of global memory per S9150, L-CSC is no longer subject to lattice size restrictions, which was the case with LOEWE-CSC and Sanam.

In order to demonstrate the power efficiency of L-CSC, the HPL-GPU implementation of the Linpack benchmark, was tuned for the particular hardware. The optimized version attempts to distribute the workload between CPU and GPU such, that it is executed most efficiently - and not necessarily as fast as possible. The cluster thus operates slightly slower, but significantly more efficient [1]. This approach was already quite successful for the Sanam cluster. In addition to the software, the processor parameters such as voltage and frequency have been tuned to operate at the optimal working point with respect to efficiency. HPL-GPU was already employed on the LOEWE-CSC and SANAM clusters and achieved the 8th and the 2nd place in the Green500 lists of the most power efficient supercomputers in the world in 2010 and 2012. With the new power efficient quad-GPU architecture, and with the new HPL-GPU features aimed at improving power efficiency, L-CSC achieved the top spot of the Green500 list in November 2014 with 5293 GFLOPS/W.

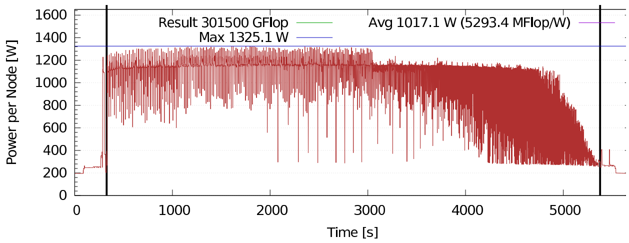

Figure 1: Power measurement of L-CSC during the Linpack run submitted to the Green500 list. The run utilized 56 nodes, the curve shows the average power per node. The final result submitted to the list is 302 TFLOPS with an efficiency of 5293.4 GFLOPS/W. This placed L-CSC 1st in the Green500 list of November 2014.

References

[1] D. Rohr, S. Kalcher, M. Bach, et al., "An Energy-Efficient Multi-GPU Supercomputer", Proceedings of the 16th IEEE International Conference on High Performance Computing and Communications, HPCC 2014, Paris, France. IEEE, 2014

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