Impact of Performance Optimizations for CFD Application on Energy and Power Consumption of Intel Xeon Scalable Processors

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In our previous paper, a set of parametric optimization techniques was developed for a real-world CFD (computational fluid dynamics) application - Multidimensional Positive Definite Advection Transport Algorithm (MPDATA), as well as the 4-step procedure for customization of the MPDATA code. Among these techniques are: islands-of-cores strategy, (3+1)D decomposition, exploiting data parallelism and simultaneous multithreading, data flow synchronization, and vectorization. The proposed adaptation methodology allows developing the automatic transformation of the MPDATA code to achieve high sustained scalable performance for all tested ccNUMA platforms with Intel processors of last generations.

The primary goal of this work is exploring the correlation between performance optimizations and power/energy consumption for a ccNUMA/SMP platform equipped with two top-of-the-line Intel Xeon Platinum 8180 CPUs, each with 28 cores. These CPUs represent the first generation of Intel Xeon Scalable processors. Besides using the RAPL infrastructure, the Yokogawa WT310 digital power meter is used to measure the power and energy of the whole platform. This provides maximally accurate and reliable results.

As the first step of our research, we evaluate the impact of the performance optimizations steps previously proposed on the energy and power consumption of the MPDATA application. Specifically, the four versions of MPDATA are examined. To reveal correlation between the power/energy consumption and performance of all MPDATA versions, we provide an insightful analysis of their interaction with the underlying hardware .

All MPDATA versions have applied various optimization steps, and in consequence they vary in terms of their performance and energy efficiency. While the performance of the first version is strongly limited by the memory bandwidth, other MPDATA versions overcome memory constraints allowing a better exploitation of the available computing resources. The proposed combination of optimization steps permits us to improve radically the efficiency of MPDATA, and reduce

both the execution time and energy consumption up to 11 and 9 times, respectively.

As the next step of our study, we investigate the effect of using the Intel AVX-512 SIMD extension on the energy consumption and performance, with different MPDATA versions. The paper reveals the benefits of utilizing the features the AVX-512 instructions in order to reduce the energy consumption for all performed tests.

This work explores also the interaction of frequency scaling with both the performance and energy efficiency. The performance-energy trade-off is experimentally determined that enables us to save the energy without any performance degradation, or with a negligible one.

Finally, we carefully compare energy measurements obtained with the Yokogawa WT310 power meter and RAPL infrastructure that basically match each others, for almost all performed tests. However, experiments performed with long-time simulation indicate some discrepancies for RAPL measurements. It is shown that they can be successfully overcome by developing an aggregate measurement methodology.

Keywords: Performance optimizations, Correlation between power/energy and performance, CFD application, MPDATA, Intel Xeon Scalable processors.