

On architecture for the future *petascale* computing.

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Abstract. The supercomputers listed in Top500 and running the HPCG benchmark are usually not able to use more than 1-5 % of their peak computing power, and no system is able to achieve 1 PFlop/s. The paper shows that the Conjugate Gradient algorithm without preconditioning requires only weak bandwidth of interconnect links, but, being a problem of low arithmetic intensity (flop/byte ratio), it would need the memory bandwidth about 20 times greater than available.

Based on this, the paper investigates architecture features of a prospective cost effective processor with the memory bandwidth matching the computing power, when solving problems of low arithmetic intensity.

Keywords. processor, memory bandwidth, HPCG benchmark, petaflops, memory controller, low arithmetic intensity

1. Introduction

The exascale (10^{18} Flop/s) computing is the leading dream and goal in HPC. Expected originally for 2016 ([2]), it is still before us, the largest system is Sunway TaihuLight (0.125 ExaFlop/s peak), U.S. Sierra and Summit are expected to come with 0.15-0.3 ExaFlop/s.

The most frequently used benchmark used to rank supercomputers is LINPACK. This benchmark is essentially the Gaussian elimination used to solve a system of linear equations and it was selected because many problems solved on supercomputers come from Numerical Linear Algebra. LINPACK results correlate well with the peak computing power (the LINPACK performance is usually 65-75 % of the peak), which makes LINPACK very popular.

However, LINPACK is a direct solver applied to dense matrices, while Linear Algebra problems solved in practice are usually sparse and very large (which prevents using direct methods). This is why a new benchmark, HPCG, was introduced in 2014. HPCG is an implementation of Conjugate Gradient Method, one of the principal iterative method of Numerical Linear Algebra, and hence it is “a method from practice”.

Surprisingly, the HPCG efficiency is extremely low - only 5.3 % for the best computer in the HPCG list that also appears in Top500, below 2.5 % for the remaining systems in HPCG Top10, and only 0.4 % for Sunway TaihuLight, see [3] and [6].

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