Abstract

We present some results concerning the computational performances of OpenFOAM [1], in terms of scalability and efficiency, on a High Performance Computing (HPC) system. This task has been accomplished by studying large, memory intensive simulations of external aerodynamics. The flow field was decomposed for running in parallel. Simulations were carried out up to 2000 cores on CRESCO HPC cluster [2], a facility of ENEA [3], the Italian Agency for Energy and New Technologies. The hardware architecture consists of 256 blades IBM HS21 each supporting dual Xeon Quad-Core Clovertown ES5345 processors (2.33 GHz, 8MB L2) for total of 2048 cores. Two network configurations have been tested: InfiniBand (4X DDR) [4] and GigaEthernet. In order to reduce the influence of I/O operations data were collected on the IBM General Parallel File System (GPFS) [5], which provides concurrent high-speed file access via InfiniBand. We also present results for the Intel Turbo Boost Nehalem E5530 processor (2.40 GHz, 8 MB L3) [6].

Methods

Hardware architecture - CRESCO HPC system is based on the leading multi-core x86_64 technology. The system consists of two main sections: (1) for high memory request and moderate parallel scalability; (2) for limited memory and high scalability cases; and an experimental section for special architectures (Cell, FPGA, CUDA). Simulations have been run on CRESCO section (2) which is composed by 256 blades IBM HS21 each supporting dual Intel Xeon Quad-Core Clovertown ES5345 processors (2.33 GHz, 8MB L2) and 16 GB RAM for total of 2048 cores. An IBM General Parallel File System (GPFS) is shared via the InfiniBand (IB) 4X DDR network interconnected. The IB network is based on a CISCO SFS 7024 (288 ports), a CISCO SFS 7012 (144 ports) and 5 CISCO SFS 7000 (120 ports), as shown in Fig.2. In CRESCO section (2) recently have been added 28 blades each supporting dual Intel Xeon Quad-Core Turbo Boost Nehalem ES530 processors (2.40 GHz, 8MB L3), 16 GB RAM for total of 224 cores.

OpenFOAM computational performances for large parallel simulations were carried out on 200 cores. Nehalem processor is about two times faster than Clovertown. Measurements indicate that Nehalem is about two times faster than Clovertown up to 200 cores. Fig.5 shows the final flow streamlines. We also have studied OpenFOAM computational performances in a case of industrial interest. We study the airflow over a car. Such kind of simulations are used in automotive industry to model the shape of cars. Often one has to try many configurations before finding the best aerodynamics. It is essential then to sensibly reduce the computational time. OpenFOAM can accomplish this task by running in parallel on large HPC systems. The geometry of the problem is shown in Fig.1. The air enters perpendicularly to the inlet at a velocity $U=39.0$ m/s. The operating pressure is $P=1$ atm. The computational domain consists of about 30 millions tetrahedral cells.

Fig.1 The geometry.

results in terms of scalability and efficiency are shown in Fig.3 for Clovertown architecture. OpenFOAM scales very well up to 2000 cores with an average efficiency of 87%. Fig.4 shows a comparison of Clovertown to Nehalem processors. Measurements indicate that Nehalem is about two times faster than Clovertown up to 200 cores. Fig.5 shows the final flow streamlines. We also have tested the GigaEthernet network. In this case the total available bandwidth is reduced (1Gb/s compared to 20 Gb/s of IB). With 64 cores the obtained speed-up is 32.21, sensibly lower than 53.4, the value obtained with IB.

References