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High-Performance Computing

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Contents

1 Introduction

In the last decade the application of High-Performance Computing have grown a lot in different fields like engineering, science and AI.

This is because some times is too difficult or too expensive to do a real life experiment, so the simulation is the only way to have some data about different phenomenon.

Also the increase in power of CPUs is not enough to keep up with the increase of computing power demand. So instead of improving the single core performance of CPUs the manufacturers decided to implement the **chiplet paradigm**. The chiplet consist in multiple chips, each with different functionalities and also different silicon dies.

1.1 Top500 list

The Top500 is a list of all the best supercomputers and data centers in the world, calculated using a specific workload HPL that solve a system of linear equation.

At the start of Top500, in 1993, the majority of supercomputer were monolith, so a single specialized architecture with high power. After the discoveries of microprocessor the best clusters became a group of machines connected between them that work in parallel as a single powerful machine. Now the architectures are heterogeneous, with CPUs augmented by accelerators, the most common being GPUs. In the future the ipotesis is that specialized architecture will come back and the nodes will become even more heterogeneous.

1.2 Components of HPC System

An HPC system is composed by different devices:

- Processors (CPU/GPU): do the computation.
- Memory (RAM): high-speed storage for active computation.
- Interconnects: high-speed network to transfer data.
- Storage
- Software: operaing system, schedulers, parallel programming tools.

Today the nodes of an HPC system can be very different between them, with general nodes (CPU based), high-throughput computational nodes (GPU based) and storage nodes with RAM and capacity storage.

The interconnection is also heterogeneous, with 3 main type of communication:

- **Intra-node**: communication between CPU,GPU and local storage. These communication have ultra-low latency (< 100 ns) and high bandwidth (> 100 GBps).
- **Intra-rack**: communication between nodes in the same rack. These communication have low latency (1-2 μs), high throughput and collective operations.
- **Inter-rack**: communication between different racks in a large cluster. Depends on the topology used (dragonfly, fat-tree,...). The major characteristics is the scalability that can handle hundred of thousands of node and also fault tolerance and congestion control.