1. Introduction & Motivation

Historically, a researcher wishing to perform computationally demanding studies has required access to a high performance supercomputer. Typically, such systems have only been available at institutions with hefty budgets: such as government labs [2], mega-corporations, or large research centers [3]. However, with the advances in off the shelf hardware, clustered systems of commodity micro-processors have become an extremely popular alternative to the big iron. A cluster is defined as a scalable architecture based on commodity hardware, a private system network, and usually running on open-source software [4]. The benefit provided by clusters is twofold:

- Cost can be greatly mitigated.
- Clusters enable institutions with less than extraordinary budgets to establish their own modestly scalable, high-performance computing (HPC) environment.

Recently, a group at Calvin College designed and built MicroWulf, a personal, portable Beowulf cluster, which provides over 26Gflops of measured performance at a total cost of less than $2500 [5]. This level of performance attained by MicroWulf was one of the first to break the $100 per Gigaflop barrier at $94 per Gigaflop.

It was the primary objective of this research to explore the means and metrics by which low-cost microprocessor clusters could be constructed and evaluated for academic use. This included looking at price and performance numbers for components, evaluating the system by industry standards, as well as experimenting with machine configurations to determine how various hardware and network configurations impacted performance.

2. Design

Due to our budget we were forced to be very selective with the components we chose. Our applications are particularly CPU bound with few network requirements. So we maximized CPU performance while budgeting all other items. We used Pentium analysis for CPU selection which was near trivial and allowed us to eliminate CPUs that lay outside of our optimal bounds running on open-source software [4]. The benefit provided by clusters is twofold:

- It currently runs #2 of the Top 500 supercomputers [5].
- Specifically Ubuntu Linux, for its ease of use and fast setup time.

Inter-node communication was implemented with MPI.

3. Software

All of our software was free which was great for our budget.

- Linux was our OS of choice.
- Specifically Ubuntu Linux, for its ease of use and fast setup time.
- MPI is standardized and portable.
- Users retain ample portion of control.
- It is a dependency of LINPACK.

We also installed two benchmarks for our evaluation:

- LINPACK: The industry standard benchmark. LINPACK primarily measures a system's double-precision floating point computational power by solving standard linear algebra routines consisting of $N \times N$ linear systems, $Ax = B$. Matrix operations occur frequently in HPC applications so the calculation of hypothetical performance is easy. However, LINPACK results do not always indicate the real capabilities of a system since I/O capabilities are not stressed.
- SIM-MASE: SIM-MASE simulates the operation and performance of applications on a variety of microprocessor configurations. It is capable of running real applications as performance impacts can be clearly shown.

4. LINPACK

We ran instances of SIM-MASE over the full range of processors, 1 through 24.

- Increasing the number of processors did not impact performance.
- Each instance maintained 60 million instructions per second regardless of the number of instances running.

While memory was a primary limiting factor for LINPACK it was not a limiting factor for SIM-MASE at all. An increase in memory concurrently would have had little return. Considering this when analyzing our SIM-MASE runs to find price/performance, an interesting result was obtained.

- In the 6 node configuration (as is) the system would yield a price/performance of $0.087/MB/s.
- In the 4 node configuration with more memory our system would have instead provided only $0.263/MB/s.
- The 4 node system would have been about 15 times worse!

5. SIM-MASE

In the 6 node configuration (as is) the system would yield a price/performance of $0.087/MB/s. However, cost efficiency would remain fixed since increasing memory is a significant investment.

Increasing the number of processors did not impact performance.

- Each instance maintained 60 million instructions per second regardless of the number of instances running.

While memory was a primary limiting factor for LINPACK it was not a limiting factor for SIM-MASE at all. An increase in memory concurrently would have had little return. Considering this when analyzing our SIM-MASE runs to find price/performance, an interesting result was obtained.

- In the 6 node configuration (as is) the system would yield a price/performance of $0.087/MB/s.
- In the 4 node configuration with more memory our system would have instead provided only $0.263/MB/s.
- The 4 node system would have been about 15 times worse!

References


I would like to thank my faculty advisor, Dr. Dan Ernst, as well as ORSP for funding.