Research and Analysis of Parallel Performance with MPI Odd-Even Sorting Algorithm on Super Cheap Computing Cluster

Khin Nyein Myint, Win Thanda Aung, Myo Hein Zaw
University of Computer Studies, Monywa
khinnyeinmyint.knm@gmail.com,winthanda.monywa@gmail.com,mheinzaw@gmail.com

Abstract

This paper is applied an odd even transposition sorting algorithm with Raspberry Pi cluster to break down a computational problem into several parallel tasks of a distributed system. According to the test results, the algorithm can apply the distributed memory of multiple nodes to sort the large dataset with the medium performance for parallel speed computing to solve the real world complex parallel and distributed computing system. In this case, it used the MPI to establish the communication and synchronization between the processors. The experiment is tested upon ten nodes Raspberry Pi (one Raspberry Pi has four cores) with forty cores computer cluster. It also compared upon the sorting method with one to forty processes on Raspberry Pi for various dataset. This work can benefit to know the HPC using super cheap cluster computer and to support the computer science students in applying the parallel and distributed computing using MPI.

Keywords: *Raspberry Pi cluster, HPC, MPI, distributed computing*

1. Introduction

Sorting is one of the most important operations in database systems and its efficiency can influences drastically the overall system performance. To speed up the performance of database system, parallelism is applied to the execution of the data administration operations. The workstations connected via a local area network allow speeding up the application processing time. Due to the importance of distributed computing power of workstations or PCs or credit card-sized computing devices like the Raspberry Pi connected in a local area network we have been studying the performance evaluation of various scientific applications.

Raspberry Pi brought multicore computing to the eager hands of many financially challenged institutions and the implementation of a free Message Passing Interface (MPI) libraries package require software for the Raspbian operating system allowed for the proliferation of computing research on a smaller budget. The Raspberry Pi was, however, unable to accommodate the resource intensive features of Mathematical, requiring users to search for ways to optimize their small Raspberry Pi for more complex computations. This led to the utilization of high performance computing which allows Raspberry Pi devices to pool resources from other Raspberry Pi devices on the same network with compatible software to operate as a cluster. A cluster is defined as a group of similar or identical computer, connected by a computer network that pool resources to provide services or run applications (Burd, 2016). Configuring computers into a cluster can exponentially increase the processing speed. This clustering technique made it possible for students and professionals to distribute workloads across machines to solve complex problems, equations and further expand the applications of the Raspberry Pi computer.

This research was primarily conducted as an independent research project by parallel and distributed computing using Raspberry Pi cluster for University of Computer (Monywa). This paper represents the outcome of a hands-on opportunity to better understand cluster computing, parallel performance using MPI libraries, odd even transition sorting algorithm and its potential benefits to higher education. This paper is organized as follows. Section 2 presents the theoretical background. In Section 3 we briefly present the related research work. In Section 4 we describe our proposed system design and implementation. Section 5 presents our experimental methodology and the evaluated results. Section 6 presents the comparison with related work. Finally, in Section 7, we present our conclusions and suggestions for future research.

2. Theoretical Background

2.1 The Odd-Even Transposition Sorting Algorithm

Odd-Even Transposition sort is a parallel sorting algorithm. It is based on the Bubble Sort technique for comparing pair wise and swapped when necessary. However these compare swaps is done in two phases: odd and even. Then it determines odd and even phase partner of the current process which has rank mpi_rank. It will need to know this in order to do the odd-even phase swaps. In this parallel sort function, it begins by allocating some memory needed later on for merging the local lists. Then, it determines the odd and even phase partner of the current process which has rank mpi_rank. If it has a process whose rank has two possible partners. It's even phase partner will have a rank of mpi_rank - 1 where as it's odd phase partner will have a rank of mpi_rank + 1. Similarly, a process whose rank is even will have an even phase partner with rank mpi_rank + 1 and an odd phase partner of rank mpi_rank -1. Next, we sort the local list using qsort .

If the system wants to sort n elements in the dataset and p processes, then receives desire input from the user (number of process and processors). To optimize the processing time this research uses fast serial sorting algorithm like Quick Sort (qsort) because of its very good time complexity (O (n log n)) [7].

2.2 The Ability of High Performance Computing

High performance computing is the use of super computer and parallel processing techniques for solving real world problems. This technology focuses on developing parallel processing algorithms and systems both administration and parallel computational techniques. HPC is the ability to process data and perform complex calculations at high speeds.HPC is also now being used not only research areas but also in industry to improve products, reduce production costs and decrease the time it takes to develop new products.

There are two models for task execution in high performance computing environments: SIMD (Single Instruction Multiple Data) and MIMD (Multiple Instruction Multiple Data). SIMD will execute the same computing instructions and operations across multiple processes at the same time. MIMD uses multiple processors to asynchronously control multiple instructions, achieving space parallelism. However, no matter which model is employed, the principal of a high performance system is consistent. The operation of a high performance unit (referring to several processors as part of a single machine or a cluster of several computers) is treated as a single computational resource, putting requests to various nodes. The high performance computing solution is an independent unit that is specifically designed and deployed as powerful computing resource [5].

2.3 Power of Cluster Computing

Cluster computing can be described as a fusion of the fields of parallel, high-performance, distributed, and high-availability computing. Cluster computing has become a hot topic of research among academic and industry community including system designers, network developers, and language designers, standardizing forums, algorithm developers, graduate students and faculties. The use of clusters as computing platform is not just limited to scientific and engineering applications; there are many business applications that can benefit from the use of clusters. There are many exciting areas of development in cluster computing with new ideas as well as hybrids of old ones being deployed for production as well as research systems. The aim of this special issue is to bring together original and latest work from both academia and industry on various issues related to cluster computing [6].

2.4. The Most Popular Computational Power (Super Cheap Cluster)

One of the challenges in the use of a computer cluster is the cost of administrating it which can at times be as high as the cost of administrating N independent machines, if the cluster has N nodes. In some cases this provides an advantage to shared memory architectures with lower administration costs [4]. This has also made super cheap clusters popular, due to the ease of administration. Raspberry Pis have really taken the embedded Linux community by storm. For those unfamiliar, however, a Raspberry Pi (Rpi) is a small (credit card sized), inexpensive single-board computer that is capable of running Linux and other lightweight operating systems which run on ARM processors. Recently many researchers try to build Rpi cluster for various purpose and so Rpi clusters analysis are very popular event in HPC technology [4].

3. Related Research Works

A group of professors from the University of Southampton created "Iridis Pi" Cluster for an attempt to provide a low –cost starting platform that would enable researchers to get to know them and can apply HPC and data processing in a range of engineering and scientific problems [1].

At the Midwest Instruction and Computing Symposium 2017 (MICS 2017), researchers from the University of Wisconsin – La Crosse presented a cluster based on eight Raspberry Pi 3 Model B modules [2]. The realized cluster was tested using the Monte Carlo method for calculating the value of Pi. Calculation was performed on eight nodes with one to four processes per node.

Alternatively, in this research 10 nodes 40 cores Rpi cluster is implemented for odd even sorting analysis using 5 million integers. The contribution of current research is mathematical model of performance using empirical methodology.

4. System Design and Implementation

An educational Raspberry Pi Cluster composed of ten computational nodes has been built to compute parallel programs. Raspberry Pi 3 model B has the following features:

−CPU: Quad-core 64-bit ARM Cortex A53, 1.2GHz

−GPU: 400 MHz Video Core IV multimedia

−Memory: 1GB LPDDR2-900 MHz SDRAM

−USB: 4 ports

−Video outputs: HDMI, composite video (PAL and NTSC)

−Network: 10/100Mbps Ethernet and 802.11n Wireless LAN

−Peripherals:17 GPIO, HAT ID Bus

−Bluetooth: 4.1

−Power source: 5V via Micro USB or GPIO header.

The appearance of the Raspberry Pi module is as shown in Figure 1.

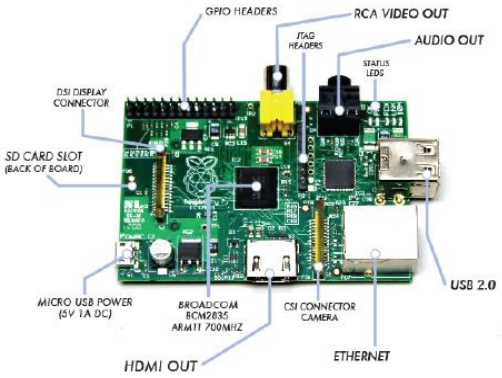

Figure 1. Raspberry Pi 3 Model B

Total ten Rpi boards are used to build super cheap cluster for this research. One single board processor consists of 4 cores. So, this cluster has 40 cores to compute any parallel execution.

Hardware Requirements for implementing this cluster and the main total costs in Myanmar kyats for build this cluster is shown in Table 1.

The total costs for implementing this 40 cores cluster is not more than 10 lakh in Myanmar kyat. So without question, it is a really super cheap cluster machine.

Software requirements of this implantation are as follow,

-Raspbian (a free operating system based on Debian GNU/Linux 9)

-Python 3.6 programming tools

-MPICH3 and MPI4Py library

Table 1. Cluster Parts List

No	Item	price	Qty	Cost
1	Rpi 3 Model B	67,000	10	670,000
2	D-link 24 port switch	80,000	1	80,000
3	USB power adapter	2,500	10	25,000
4	8 GSD card	8,000	10	80,000
5	60.5meter network cable	3,000	10	30,000
6	Pi Cluster Frame	20,000	2	40,000
Total Cost (in Myanmar Kyats)				925,000

Architecture design for current research is shown in Figure 2.

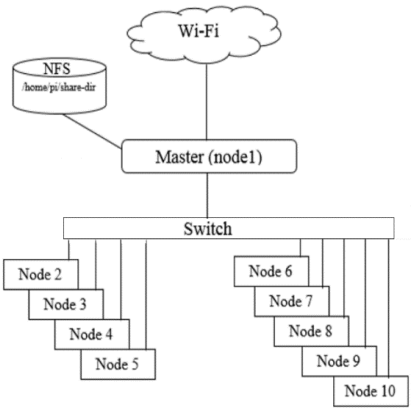

Figure 2. High Performance Computing System Architecture

According to the logical modal and network diagram, bench mark Rpi cluster is implemented. The appearance 10 nodes and 40 cores Rpi rack cluster of UCS Monywa is as shown in Figure 3.

Figure 3. An appearance of implemented cluster

Consequently evaluation of each node is tuned by well know MPI library program. The performance of each node is shown in Figure 4. The evaluation of each node is 2.942 e^{-01} Gflop. This result is really good more than expectation and feasible to use in computer engineering simulation and HPC.

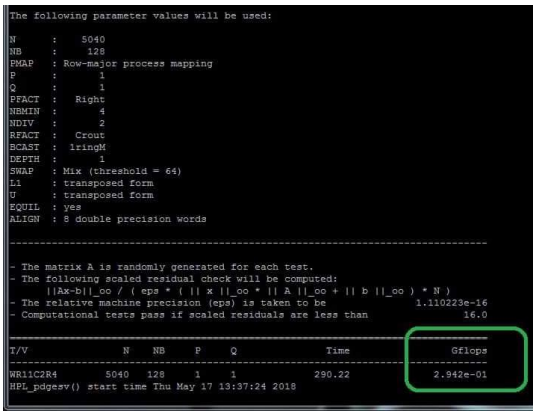

Figure 4. Evaluation of each node

As a consequently 40 core clusters is used to sort odd even sorting algorithm. The total number of integer is 5 millions. These numbers are generated from pseudo random number generator. According to the mathematical formulation, 5 million integers are gotten and then categorized by odd even phase. After that, sorting in ascending order with 40 cores processors.

5. Experimental Results

These 5 millions integers are handled by selected cores of processor depend of various thread from 1 to 40. After that, mathematical model is driven based on the results of the research using empirical method.

The bench mark cluster is built using proposed logical model and then performance of N processors is denoted. Follow by the Gustafson's Law, to get the peak performance of cluster the tasks is divided into 40 processes for Rpi 40 cores cluster. The performance results depend upon the number of processors and threads are shown in Table 2.

Table 2. Processor and Time

Processor	time(s)
2	67
3	43
4	31
5	25
6	22
7	19
8	17
9	15
10	13

According to the results, performance versus number of processors and thread graph is shown in Figure 5.

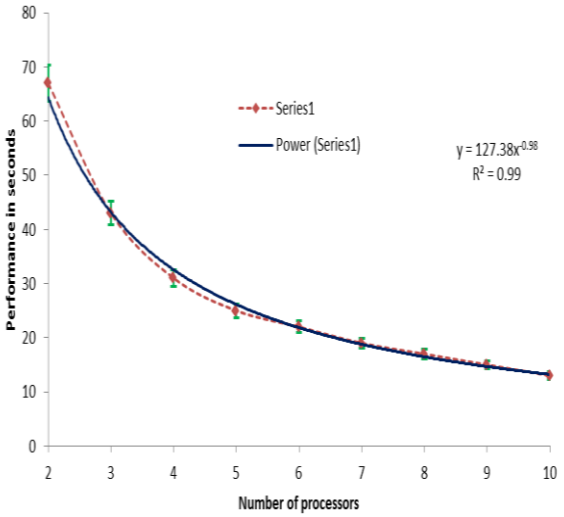

Figure 5. Analysis of parallel performance using odd-even sort

Applying empirical research methodology, mathematical trend line is driven as follow,

$$T \alpha x^{*}e^{-z} \quad (1)$$

Where T – performance of N cores cluster

x – number of processors

This means that T is directly proportional to number of process in Equation (1). Rpi clusters performance is depend on the number of processor in exponentially. Hence, performance of N cores cluster for N processes can be predicted as follow:

$$T = k^{*}x^{*}e^{-z} \quad (2)$$

Where - k = 127.38

z = 0.98

The proposed mathematical model is the accuracy of 99% and tolerance is 1% in empirical methodology.

6. Comparison with Related Work

Iridis Pi is just an implementation of super-cheap cluster [1]. However, Midwest Instruction and Computing Symposium 2017 resultant pi cluster is used the Monte Carlo method (403/500) for calculating the value of π [2]. At that research, the maximum performance with 4 processes is 24.39 seconds for π value. Despite the different purpose, odd even analysis with 10 nods Rpi cluster of current research's performance is 13 seconds for sorting odd and even of 5 millions integers. Therefore, current research works outcome cluster can be used for more complex scientific application.

7. Conclusion and Further Extension

Overall, the Rpi Cluster has proved quite successful. The performance has shown perfectly acceptable for research simulation. Cluster computing environment using raspberry pi which is very cheap and feasible to use. As in today's world there is much emphasis placed on, using the commodity-based hardware and software components to achieve high performances and scalability and at the same time keep the ratio of price versus performance low. This research tries to recognize the importance and uses of Cluster Computing in the IT industry. This innovated research aimed to demonstrate the prowess of cluster computing and data analytics. It can be used as a learning ground for institutions and be used in various scaled industries and research as well. As a subjected research area, large data amount 5 million integers are categorized by odd and even in ascending order. The results are pretty good. Moreover, the contribution of this current adaptive research is really useful to predict performance based on the numbers of cluster node and process. The computer hardware —the Raspberry Pi 3— can be replaced with any computer system with a network interface. In the scope of single board computers there are many different alternatives available. These alternatives (such as Parallella and ODROID-C2) may have different advantages in performance, economic aspects and simplicity of electronic setup.

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