A Comparative Study of various Computing Processing Environments: A Review

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Abstract— **Off recent, there has been an increased interest in reducing computing processors powers and improve system throughout. This has led to the design and redesign of multi-core processors that have been rolled out to meet the ever increasing computational problems. Complex problems have emerged in the IT and ICT world which have led to the evolution of traditional computing environments in order to meet today's demand. Most of the traditional computing processors were homogenous i.e. they had the same characteristics. Homogenous processing environments were overwhelmed by the increasing work load which led to the evolution of heterogeneous processing environments. These have different characteristics for the same processor unlike the homogenous processors. The aim of this paper is to bring out the differences between the parallel computing which includes clusters, grids and cloud processing environments and serial computing which includes homogenous and heterogeneous computing environments.**

Keywords— **Processing environments, homogenous environments, heterogeneous environments, grid computing, cluster computing, cloud computing.**

I. INTRODUCTION

Applications of the modern day are continuously evolving in the need for more computing resources and a need for 24x7 hours availability service. In light of this, different computing environments have been developed to match up the scaling requirements of today's applications. This paper presents a comparative analysis of the major serial and parallel computing processing environments.

The definitions of computing environments which are homogenous and heterogeneous are dependent on the application. These definitions are further classified based on the hardware, communication layer and the software available. A homogenous system guarantees similar results and storage representation on each hardware processor and the compiler options also guaranteeing similar results on floating points compilations. A computing environment that is heterogeneous can, therefore, be simply described as one, that is not homogenous in nature.

As more complex computations emerged, there arose a need to improve processing speed. This led to the design of processors that could solve problems in parallel, hence, parallel computing. Unlike in homogenous and heterogeneous environments where the problems had to be solved sequentially, problems could now be solved simultaneously. These problems could be broken up into discrete parts with each part being broken down into individual instructions. The instructions could be executed by different processors and at different geographical locations [1].

Parallel computation is considered as high end computation and involves breaking up of problems into smaller parts and solving them concurrently [8]. Parallel computing brought about grids, clusters and clouds. Some of the main reasons for developing parallel computing were to increase processing speeds, share resources and allow simultaneous access of a sharable resource. The basic idea was to use many computer processors simultaneously but present it as a single computer interface to a user.

On the other hand, grid computing is an attempt to provide scalable and seamless access to widely distributed resources [2]. Expensive and remote resources can be aggregated and shared on computational grids. These resources may be widely geographically located but shared on computer clusters and presented as a single harmonized computer for solving data intensive and large scale computations.

Cluster computing is more like grid computing with the difference being use if cluster rather than grids. Clusters can be distributed or parallel systems that are made up of interconnected computers working together as a single resource [5].

Cloud computing is the use of computing resources (hardware and software) that are delivered as a service over a network (typically the Internet). Cloud computing entrusts remote services with a user's data, software and computation [14].

II. HOMOGENEOUS COMPUTING ENVIRONMENT

Exclusively, the following conditions should be satisfied for a system to be considered as homogeneous: [3]

1. The hardware of processor ensures the same storage representation and the same results for operations on floating point numbers.
2. In case of a floating point number is communicated between processors, the communication layer guarantees the exact transmittal of the floating point value.
3. The software module (operating system, compiler, compiler options) on each processor also guarantees the same storage representation and the same results for operations on floating point numbers.

It is considered that a homogeneous machine as one which satisfies condition (1); a homogeneous network as a group of homogeneous systems that additionally satisfies condition (2); and finally, a homogeneous computing environment as a homogeneous network which satisfies condition (3). The requirements for a homogeneous computing environment are rigorous and are frequently not met in networks of workstations or systems, even when each computer in the network is the same model.

III. HETEROGENEOUS COMPUTING ENVIRONMENT

Heterogeneous Computing refers to those systems that make use of different types of computational units. The computational unit can be a general-purpose processor, a special-purpose processor, or a co-processor. Traditionally, the heterogeneous computing platform consists of processors with different instruction set architectures. The need for increased heterogeneity in the computing systems is partially as the need for high-performance, highly reactive systems that interact with other environments too [6]. In past, the huge advances in technology and frequency scaling allowed the mainstream of computer applications to escalate in performance without requiring structural changes or custom hardware quickening. As these advances continue, their effect on modern applications is not as dramatic as other obstacles such as the memory-wall and power-wall come into play. With these additional constraints, the main method of gaining extra performance out of computing systems is to introduce additional specialized resources, thus making a computing system heterogeneous. In the addition of extra, independent computing resources necessarily allows most heterogeneous systems to be considered parallel computing or multi-core computing systems.

Heterogeneous platforms require the usage of multiple compilers in order to target the assorted compute elements in such platforms. It results in more complicated development process compared to homogeneous systems process as multiple compilers and linkers should be used together in a cohesive method to properly target a heterogeneous platform.

TABLE 1. HOMOGENOUS VS. HETEROGENEOUS PROCESSING ENVIRONMENTS

Parameter	Homogenous Computing	Heterogeneous Computing
Storage	Same storage representation for each hardware processor.	Different storage representation in processor registers.
Result on computation of floating point numbers	Same results for operations on floating point numbers.	Results may vary from one core processor to another on the precision of floating point computations.
Transmission of floating point numbers	Unaltered transmission of floating point numbers, i.e., transmitted numbers same as received on different processors.	Precision of floating point numbers vary from one processor to another. Communication layer doesn't guarantee exact transmission.
Operation on floating point numbers	Same results and storage representation guaranteed by the compiler options and operating system.	May vary in precision of results in floating point operations and storage representation.
Performance	Low serial performance with simple cores.	High parallel performance with simple processor cores and high serial performance with complex processor cores.
Execution time	Increased execution time for several tasks with overall reduction in performance.	Reduced execution time for several tasks with overall increase in performance.
Throughput	Fewer tasks completed per unit time.	More tasks completed per unit time.
Power consumption	Low power consumption	High power consumption

IV. GRID COMPUTING ENVIRONMENT

The grid computing is basically a way to execute jobs across a distributed set of processors. Grid computing offers sharing of resources over geographically distributed locations. Furthermore, collaborative nature of grids leads to the concept of virtual organizations consisting of a dynamic set of data and resources to solve a specific task. The architecture of grid computing is shown in Figure 1. Grid computing divides a large program into sub-programs and assigns each sub-program to an individual processor [10]. Each processor would now process the sub-program and would return the end result. Even if one processor fails, the result would not get affected because the task will be reassigned to other processor. A variety of resources may be shared, including computers, storage devices, sensors, scientific instruments, network, software or data. In Grid, every processing node is autonomous i.e. it has its own administration and control and behaves like an independent entity.

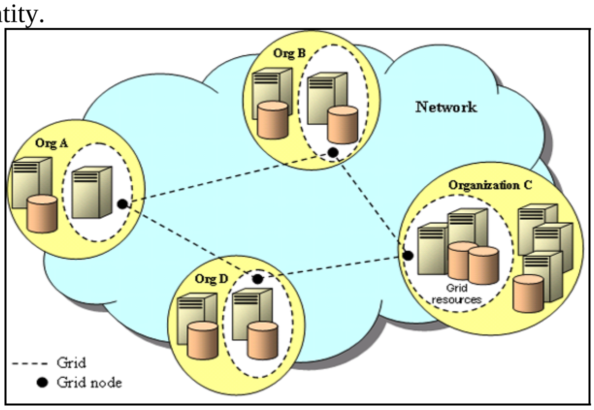

Figure 1. Grid Computing

Grids can further be categorized in two; Computational grids – these are grids that primarily focus on intensive and complex computations, data grids – grids for management and control of sharing of vast amounts of data [7].

Distributed or grid computing, traditionally is a special type of parallel computing relying on complete computers (with onboard CPUs, storage, power supplies, network interfaces, etc.) connected to a network (private, public or the Internet) by a conventional network interface, such as Ethernet. This is in contrast to traditional notion of a supercomputer that has many processors connected by a local high-speed computer bus.

V. CLUSTER COMPUTING ENVIRONMENT

Cluster computing is a platform that combines commercial off-the-shelf computers with a high speed network to form a single powerful super computer. The use of clusters as computing platform is not just limited to scientific and engineering applications; there are many business applications that get benefit from the use of clusters. This technology improves the performance of applications by approaching parallelism, simultaneously on different machines and also enables shared use of distributed resources. The architecture of Cluster computing is shown in Figure 2. Basically, a cluster is a type of parallel or distributed computer system, which consists of a collection of inter-connected stand-alone computers working together as a single integrated computing resource. When several computers are connected to a high speed network they consume a single resource pool and these grouped computers are called clusters.

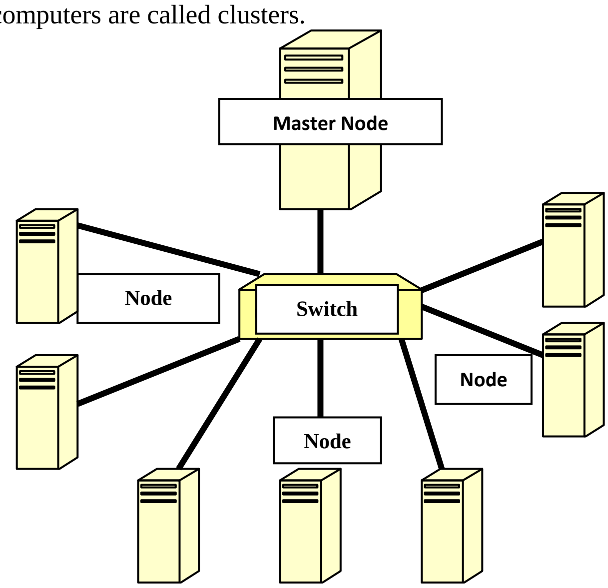

Figure 2. Cluster Computing

Computers in a cluster network are attached in tightly coupled fashion i.e. they all use the same subnet and follow the same domain and networked with very high bandwidth connection and they all use the same hardware and software. In cluster computing environment users request is distributed among various computers in a network. The advantage of doing this is to increase the performance and processing of the task becomes fast.

VI. Cloud Computing Environment

Cloud can be defined as a pool of resources which includes storage, servers, database, network; software etc. and computing can be defined as the activity of using and improving the computer hardware and software. Thus, Cloud Computing as shown in Figure 3, is the delivery of applications, infrastructure and platform as a service over the Internet accessible from the web browser and desktop with the end user not having any knowledge of the service providing system, as well as of where the software and data are residing on the servers on a pay-per-use basis. Grid computing is simply one type of underlying technologies for implementing cloud computing [11], [13].

Basically a cloud is of two types; Public cloud - the information and applications running may be accessed from the internet. Private cloud - the information and applications running may be accessed from the intranet via a VPN connection between the internal datacenter and the outsourced infrastructure.

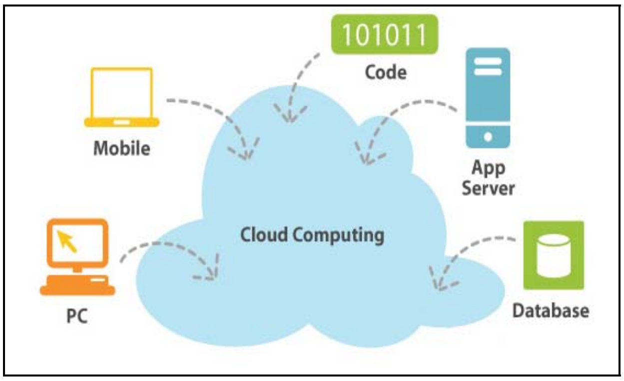

Figure 3. Cloud Computing

The difference between grid computing, cluster computing and cloud computing processing environments is given in Table 2.

Table 2. Grid Computing Vs. Cluster Computing Vs. Cloud Computing

Parameter	Grid Computing	Cluster Computing	Cloud Computing
Heterogeneous/homogeneous	Grids are heterogeneous. Similar to heterogeneous computing characteristics for the whole grid.	Clusters are homogeneous. Similar to homogeneous computing characteristics for the whole cluster.	Clouds are either homogeneous or heterogeneous in nature.
Hardware & Operating System	Computers on grids can have different hardware and different operating systems hardware interfaces.	Computers on clusters have similar hardware and same operating system.	Computers on cloud are managed by the operating system of the basic physical cloud units.
Dedication	Can make use of spare computation power on a desktop computer.	Dedicated to work as a single unit. Cannot make use of computation power outside the grid.	Allows multiple smaller applications to run at the same time.
Distribution	Distributable over LAN, Metropolitan and WAN.	Contained in a single location only.	Clouds are mainly distributed over MAN.
Resource handling	Every node is independent. Each has a specific resource manager to it and behaves as an autonomous entity.	Resources are handled by a centralized resource manager and all the nodes presented as a single coherent system.	Every node acts as an independent entity.
Centralization	Decentralized and loosely coupled.	Centralized and closely coupled.	Dynamic computing infrastructure
Job management & scheduling	Decentralized job scheduling and job management.	Centralized job scheduling and management.	Minimally or self-managed platform.
End user presentation	Presented as a dynamic and diversified system.	Presented as a single system image.	Presented as a Self-service based usage model.
Areas of Applications	Predictive Modeling and Simulations, Engineering Design and Automation, Energy Resources Exploration, Medical, Military and Basic Research, Visualization etc.	Educational resources, Commercial sectors for industrial promotion, Medical research etc.	Banking, Insurance, Weather Forecasting, Space Exploration, Software as a service Infrastructure- as -a-Service etc.

VII. CONCLUSION

Computing systems have evolved at a fast pace since the homogeneous systems of serial computing were first used. The changes and advancements that have occurred and the differences that are there between the sequential method and the modern parallel computation are so vast to be captured in this short paper. This paper has therefore, highlighted a comparative description of the major differences between homogeneous and heterogeneous computing environments.

Parallel computing being a wide topic also by itself has been discussed under grid and cluster computing. Grids and clusters have been developed with the same goal of resource sharing, reduction in tasks execution time and allowance of simultaneous access of a single resource. Although usually confused, this paper has tried to highlight the major differences between the two with the main difference being the homogeneous nature of cluster computing and heterogeneous for grid computing.

The variation between grid and cluster computing on the one hand and cloud computing on the other are attributable to the system dynamics. Resources in grid and cluster environments are normally pre-reserved, while cloud computing systems are dependent on the user needs. Service usage only tends to be accurately measured in grid and cloud computing systems, whereas the cluster environment simply provides elementary functions.

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