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A Comparative Analysis of some High Performance Computing Technologies

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Abstract: Computing is an evolutionary process. As part of this evolution, the computing requirements driven by applications have always outpaced the available technology. The system designers have been always seeking for faster and more efficient systems of computing. During the past decade, many different computer systems supporting high performance computing have emerged. Their taxonomy is based on how their processors, memory and interconnect are laid out. Today's applications require high computational power as well as high communication performance. The high performance computing provides an approach to parallel processing that yields super computer level performance solving incredibly large and complex problems. This trend makes it very promising to build high performance computing environment with a cost effective approach.

Keywords: cluster computing; grid computing; cloud computing; ubiquitous computing; mobile computing.

I. INTRODUCTION

During the last several decades, dramatic advances in high performance computing technology have allowed the human race to generate, process and share information in new ways. As new applications of computing technology are developed and introduced, it leads to new demands for even more powerful computing infrastructure. To meet these computing infrastructure demands, very large powerful systems are assembled from many small, inexpensive commodity components [1-2]. Because now-a-days computers have become smaller and less expensive, disk drive capacity continues to increase and networks have gotten faster. Such systems tend to be less costly than a single, faster machine with comparable capabilities.

However, several commercial and academic organizations have built large systems from commodity computers, disks and networks have created software to make this hardware easier to program and manage [54]. These organizations use their hardware and software to provide storage, computational and data management services to their own internal users as well as external users across the globe. The present availability of high capacity networks, low cost computers and storage devices as well as the widespread adoption of hardware virtualization, service oriented architecture, autonomic and utility computing have led to a growth in high performance computing [3-4].

The rest of the paper is organized into three parts. In Section 2, the high performance computing systems and concepts of high performance computing technologies are described. The Section 3 makes the performance comparison of various high performance technology based on various performance measure parameters. Finally, we draw our conclusion in the Section 4.

II. HIGH PERFORMANCE COMPUTING SYSTEMS

High performance computing is the evolution and adoption of existing technologies and paradigms. The goal of high performance computing is to allow users to take benefit from all the technologies without the need for deep knowledge about or expertise with each one of them. High performance computing systems combine some of the attributes and also shares many of the same attributes among themselves [5-6,56]. High performance computing systems focuses on maximizing the effectiveness of the shared resources. High performance computing resources are usually not only shared by multiple users but also dynamically reallocated as per demand. High performance computing is a technology that uses the internet and remote servers to maintain data and applications [7-9]. This technology allows for efficient computing by centralizing data storage, processing and bandwidth. High performance computing systems are broken down into three segments: application, storage and connectivity. Hence the high performance computing includes some of similar type of systems: Cluster computing, Grid computing, Cloud computing and Mobile Cloud computing.

A. *Cluster Computing*

The high performance cluster provides an approach to parallel processing that yields super computer level performance. Clusters present their own set of challenges with superior performance and excellent price/performance ratio. The cluster computing provides a balanced system with high throughput, outstanding availability, robust memory, sustainable i/o and leading edge productivity tools i.e. easy to manage and maintain for complex tasks. Clusters are designed to deliver high performance, high scalability and to offer low cost effective system management [10-12].

Cluster Computing Systems: A typical computer cluster usually consists of a set of tightly connected computers that work together so that in many respects they can be viewed as a single system. Each machine in the cluster is a complete computer consisting of one or more CPUs, memory, disk drives and network interfaces [13]. The components of a cluster are usually connected to each other through fast LAN with each node running its own instance of an operating system [14-16]. Another important characteristic of a cluster is that it is owned and operated by a single administrative entity. The software used to program and manage clusters give users the illusion that they are with a single large computer when in reality the cluster may consists of hundreds or thousands of individual machines [17-18]. The architecture of a cluster is shown in Fig1 [10].

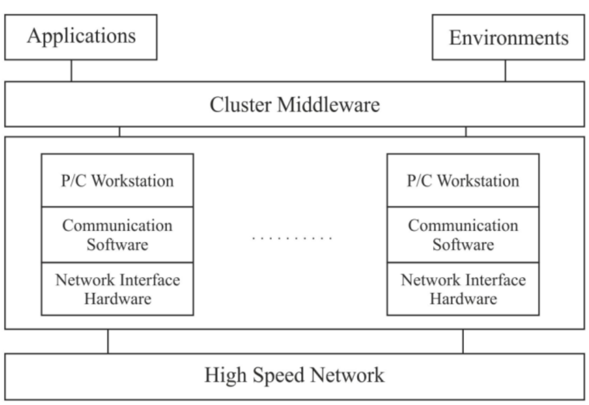

Fig 1: Cluster Computing Architecture

The cluster middleware is responsible for offering an illusion of an unified system image (SSI) and availability out of a collection on independent but interconnected computers [19]. Programming environment can offer portable, efficient, easy to use development application. They include message passing libraries, debuggers and profilers s.a. compilers, PVM and MPI. Applications can be sequential, parallel or distributed s.a. system management tools [57].

From the high performance and scalability perspective the clusters are referred as workstation clusters or network of workstations where a cluster is a configuration of a group of independent servers managed as a single system sharing a common address space [20]. It is defined specifically to tolerate component failures and to support addition and removal of components in a way i.e. transparent to users. In case of failures of a hardware or software components in the primary system the critical application can be transferred to the secondary server, avoiding downtime and guaranteeing application's availability. This process is termed as failover and inevitably implies a temporary degradation of the service but without total permanent loss. The fault tolerant server provides continuous service in case of failures with the increasing performance needs [21-22].

Load balancing is a technique for scaling performance by distributing load among multiple clusters. A cluster provides high availability by making data and applications availability on several clusters linked together [23-24]. If one cluster stops functioning a process called failover automatically shifts the workload of the failed cluster to another cluster. After the failed cluster recovers, it rejoins the cluster system and is known as failback. Load balancing provides failover and failback support for continuous cluster availability. Load balancing technique is also used to enhance scalability which boost throughput while keeping response times low. The ability to easily transfer load within a fault tolerant cluster provides outstanding availability during system maintenance activities, when the maintenance is complete, the node rejoins the cluster and assumes its normal workload [25]. This robust fault tolerance in clusters makes recovery from failures in a reasonably short time. An effective load balancing scheme maximizes the efficiency by minimizing the processor idle time and inter processor communication. e.g. a web server cluster may assign different queries to different nodes, so the overall response time will be optimized [26].

Clusters emerged as a result of convergence of a number of computing trends including the availability of low cost microprocessors, high speed networks and software for high performance distributed computing [27]. Clusters are usually deployed to improve performance and availability over that of a single computer, while typically being much more cost effective than single computers of comparable speed or availability. Clusters are typically used for scientific or commercial applications that can be parallelized. Since clusters can be built out of commodity components, they are often less expensive to construct and operate than supercomputers [58].

B. *Grid Computing*

Grid computing is rapidly emerging as the dominant paradigm for wide area distributed computing. Grids are a form of distributed computing whereby a super virtual computer is composed of many networked loosely coupled computers acting together to perform very large tasks [28]. Grid computing is the ability, using a set of open standards and protocols to gain access to applications and data, processing power, storage capacity and a vast array of other computing resources over the internet. A grid is a type of parallel and distributed systems that enables the sharing, selection and aggregation of resources distributed across multiple admin domains based on their resource availability, capability, performance, cost and user's quality of service requirements [29-30].

Its goal is to provide a service oriented infrastructure that leverages standardized protocols and services to enable pervasive access and co-ordinated sharing of geographically distributed hardware, software and information resources. An environment that provides the ability to share and transparently access resources across a distributed and heterogeneous environment not only requires the technology to virtualised certain resources but also technologies and standards in the areas of scheduling, security, accounting, system managements and so on [31-32].

Grid computing differs from conventional high performance cluster computing systems in that grid tends to be more loosely coupled, heterogeneous and geographically dispersed. A grid computer is a multiple number of same class of computers clustered together [28]. A grid computer is connected through a super fast network and shares the devices like disk drives, mass storage, printers and RAM. Grid computing is a cost efficient solution with respect to super computing. Grid computing combines computers from multiple administrative domains to reach a common goal to solve a single task and may then disappear just as quickly [33].

Grid Computing System: Grid computing focused on aggregation of geographically distributed resources spanning multiple admin domains. Aggregation included both the aggregation of capacity i.e. clustering of individual systems to increase computational power or storage capacity as well as the aggregation of capability i.e. combining a specialized instruction with a large storage system and a computing cluster. The aggregation of resources is for the realization of virtual organizations and the development of application that can exploit such an aggregated execution environment [34]. Grids can be built in all sizes, ranging from just a few machines in a department to groups of machines organized as a hierarchy spanning the world. A simple grid consists of just a few machines, all of the same hardware architectures and same operating system, connected on a LAN as shown in the Fig.2 [35].

This kind of grid uses homogeneous systems so there are fewer considerations and may be used for specialized applications. The machines are usually in one department of an organization and their use as a grid may not require any special policies or security concerns. Because the machines have the same architecture and operating system, choosing application software for these machines is usually simple. It is a cluster implementation for a grid [36].

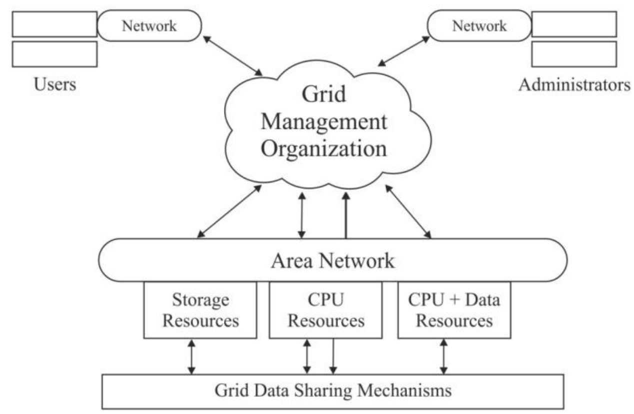

Fig.2. Grid Computing Architecture

The next progression is to include heterogeneous machines. Machines participating in the grid may include systems from multiple departments but within the same organization [60-61]. Such a grid with single organization, single cluster and with no partner integration is referred to as an intragrid [68]. The grid may grow geographically in an organization that has facilities in different cities. The technologies may be used over the internet to connect the different parts of the organization. Such a grid with multiple organizations, multiple clusters with partner integration is referred to as an extragrid [68]. A grid may grow to cross organization boundaries and may be used to collaborate on projects of common interest. This type of grid is known as intergrid [68-69].

Grid middleware is a specific software product, which enables the sharing of heterogeneous resources and virtual organizations. Utility computing is referred to as the provision of grid computing and applications as service either as an open grid utility or as a hosting solution for one organization or a virtual organization [37]. Software as a service (SaaS) is software that is owned, delivered and managed remotely by one or more providers [74]. The potential grid users play an important role for grid adoption.Grid computing is a cost effective way to use a given amount of computer resources. It solves problems that need a tremendous amount of computing power [37]. The resources of several computers can be shared co-operatively without one computer managing the other.

C. Cloud Computing

Cloud computing get its name as a metaphor for the internet. Cloud computing is a colloquial expression used to describe a variety of different types of computing concepts that involve a large number of computers that are connected through a real time communication network typically the internet [38]. The internet is represented in network diagram as a cloud. The cloud icon represents "all that other stuff" that makes the network work. Cloud computing is also a synonym for distributed computing over a network and means the ability to run a program on many connected computers at the same time [39-40].

Grid computing is often confused with cloud computing. Grid computing applies the resources of numerous computers in a network to work on a single problem at the same time. In grid computing, a large project is divided among multiple computers to make use of their resources while cloud computing does just the opposite. It allows smaller applications to run at the same time [41].

Cloud Computing System: Cloud computing is not a "one-size-fits-all" affair. There are several different ways the infrastructure can be deployed depending on the application and how the provider has chosen to build the cloud solution [42]. A simple cloud computing is made up of clients, datacenter and distributed servers as shown in Fig.3 [64, 78].

Clients in a cloud computing architecture are the computers with LAN. They might be laptops, tablets, mobile phones or PDAs. Clients generally fall into three categories: Mobile, Thick and Thin Client [43]. The mobile devices include PDAs or smartphones like a blackberry with mobile smartphone or an iphone. The thick client is a regular computer using a web browser like Firefox or Internet Explorer to connect to the cloud. The thin clients are computers that do not have internal hard devices, rather let the server do all the work and then display the information. A data center is the collection of servers where the application to which the subscriber is housed. Softwares can be installed allowing multiple instances of virtual servers to be used. The distributed servers are in geographically disparate locations. If a failure causes in one site, the service would still be accessed through another site. And if the cloud needs more hardware, they can add them at another site and simply make it part of the cloud [44].

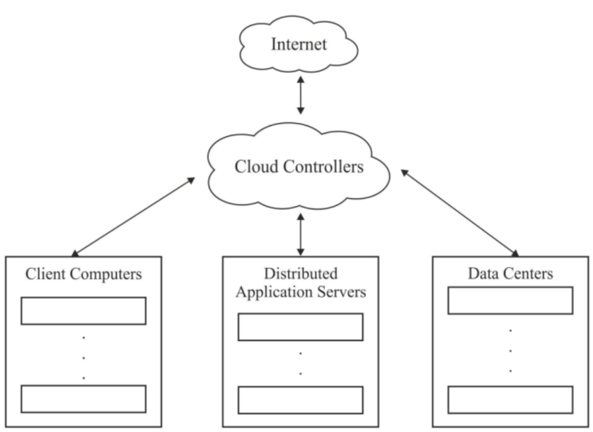

Fig.3. Cloud Computing Architecture

A cloud is operated solely for a single organization whether managed internally or by a third party and hosted internally or externally is referred as private cloud [70]. The cloud that is available to the public on a commercial basis by a cloud service provider is a public cloud [71]. And the community cloud shares its infrastructure between several organization with similar interests and requirements. The operation may be in house or with a third party on the premises [72]. Hybrid cloud consists of a number of clouds of any type where the clouds have the ability through their interfaces to allow data and/or applications to be moved from one cloud to another [73].

The term services in cloud computing is the concept of being able to use reusable, fine grained components across a vendor's network. This is widely known as "as a service" which offers low barriers (makes available to small business), multitenacy (resources to be shared by many users), device independence (allows users to access the systems on different hardware) and large scalability [44]. The different types of fundamental service models are Software As A Service (SaaS), Platform As A Service (PaaS), Infrastructure As A Service (IaaS) and Network As A Service (NaaS).

SaaS is a model in which an application is hosted as a service to customers who access it via the internet. Saas is also referred as "On demand software" providing users access to application software and databases through cloning tasks onto multiple virtual machines at run time to meet changing work demand. It is common to refer to special types of cloud based application software with a similar naming convention- desktop as a service, business process as a service, test environment as a service, and community as a service. SaaS was developed specifically to use web tools like the browser. This makes them web native. It was also built with a multitenant back end in mind, which enables multiple customers to use an application [74]. Pass delivers a computing platform including operating system, programming language execution environment, database and web server. It supplies all the resources required to build applications and services completely from the internet without having to download or install software. Paas has the ability of geographically isolated development teams to work together and to merge web services from multiple sources [75]. In IaaS, physical infrastructure is abstracted to provide computing, storage and networking as a service avoiding the expense and need for dedicated systems. IaaS also reffered as hardware as a service (HaaS). It allows to rent resources like server space, network equipment, memory, CPU cycles and storage space. HaaS offers hardware for firewalls, routers and load balancing. It provides internet connectivity and platform virtualization environment with virtual machines [76]. NaaS provides the cloud service user to use network or transport connectivity services and/or inter cloud network connectivity services [77].

D. *Mobile Cloud Computing*

Mobile computing are increasingly becoming an essential part of human life as the most effective and convenient communication tools not bounded by time and place which run on the devices and/or on remote servers wireless network [45]. Ubiquitous computing refers to a new genre of computing in which the computer completely penetrates the life of user. Ubiquitous or pervasive computing access to computer network all the time at any location by any person where our tasks are powerfully though invisibly, assisted by computers. It can not be realized unless mobile computing matures [46-47]. Nomadic computing refers to limited migration within a building at a pedestrian speed. Users carrying laptop with dial-up modems are engaged in nomadic computing. Mobile computing requires wireless network to support outdoor mobility and handoff from one network to the next at a pedestrian or vehicular speed. Traveler in car using laptop connected with a GSM phone are engaged in mobile computing Mobile computing affects entire spectrum of issues in computing [48].

Mobile computing is the discipline for creating an information management platform, which is free from spatial and temporal constraints. This allows its users to access and process desired information from anywhere in the space. A user can continue to access and manipulate desired data while travelling on plane, in car, on ship etc. Thus the discipline creates an illusion that the desired data and sufficient processing power are available on the spot, where as in reality they may be located far away [45, 65].

The discipline of mobile computing has its origin in personal communication Services (PCS) [66]. PCS refers to a wide variety of wireless access and personal mobility services provided through a small terminal like cell phone. It enables communications at any time, at any place and in any form. PCS are connected to public switched telephone network (PSTN) to provide access to wired telephones [67]. PCS include high tier digital cellular system for widespread vehicular and pedestrian services and low tier telecommunication system standards for residential, business and public cordless access applications.

Mobile Cloud Computing System: Together with an explosive growth of the mobile applications and emerging of cloud computing concept, mobile cloud computing has been introduced to be a potential technique for mobile services. Mobile cloud computing integrates the cloud computing into the mobile environment and overcomes obstacles related to the performance in terms of battery life, storage and bandwidth, environment in terms of heterogeneity, scalability , availability and security [49-50]. Mobile cloud computing can be defined as a combination of mobile web and cloud computing which is the most popular tool for mobile users to access applications and services on the internet. It provides mobile users with the data processing and storage services in clouds. The mobile devices do not need a powerful configuration such as CPU speed and memory capacity since all the complicated computing modules can be processed in clouds [51].

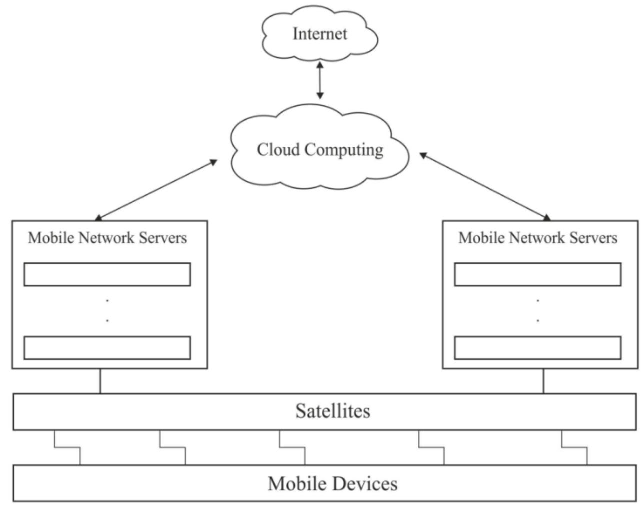

Fig.4. Architecture of Mobile Cloud Computing

The general architecture of mobile cloud computing is shown in Fig.4, where the mobile devices are connected to the mobile networks via satellites that establish and control the air link connections to provide functional interface between the networks and mobile devices. Mobile users requests and information are transmitted to the central mobile network servers (MNS) that are connected to processors of mobile network operator (MNO) providing mobile network services. Hence MNOs provide services to mobile users after authentication, authorization and accounting verification based on subscriber's and agent's data stored in database. Then the requests are delivered to a cloud through internet. In the cloud, cloud controllers process the requests to provide mobile users with the corresponding cloud services. These services are developed with the concept of utility computing, ubiquitous computing, virtualization and service oriented architecture such as web, application and database servers [52-53].

To facilitate data management activities with the accommodation of internet and multimedia services, users can carry personal digital assistant (PDA), laptop, palmtop, cell phones etc. this connectivity mode is called as mobile connectivity. The mobile connectivity between two nodes exists if they are continuously connected through wireless channel and can utilize the channel without being subjected to spatial and temporal constraints [54]. Wireless data connections used in mobile computing take three general forms: Cellular data services s.a. GSM, CDM or GPRS with 3G network s.a. W-CDMA, EDGE or CDMA-200 usually available within range of commercial cell towers [62]. Wi-Fi connections offer higher performance may be either on a private business network or accessed through public hotspots [63]. Satellite internet access covers areas where cellular and Wi-Fi are not available when using mix of networks, a mobile virtual private network handles the security concerns, performs multiple network logins, keeps application connections alive, prevent crashes or data loss during network transitions [55,59].

III. COMPARISION OF HIGH PERFORMANCE TECHNOLOGIES

Based on the performance of cluster computing, grid computing, cloud computing and mobile cloud computing, the summary of comparison on several parameters is evaluated and given in Table 1.

IV. CONCLUSION

Most of current approaches to high performance computing are built on cloud computing which is built on clusters. Some organizations have multiple clusters in multiple data centers. But these clusters typically operate as isolated systems. A cloud architecture that could make multiple geographically distributed clusters appears to users as a single large cloud would provide opportunities to share data and perform even more complex computations.

The cloud, which could share many of the same characteristics as a grid, could be easier to program, use and manage than grids. Mobile computing also has enormous applicability. It is one of the main component of today's IT s.a. e-commerce and web etc. Mobile computing is an interface to the cloud computing. With the explosionof mobile applications and support of cluster computing for a variety of services, mobile cloud computing is introduced as an integration of cloud computing into mobile computing. Mobile cloud computing brings new types of services and facilities for mobile users to take full advantage of cloud computing.

Table 1: Summary of Performance Comparison of High Performance Computing Technologies

Parameters	***Cluster Computing***	***Grid Computing***	***Cloud Computing***	***Mobile Cloud Computing***
Architecture	Centralized	Geographically Distributed	Geographically Isolated	Geographically Distributed
Setup	Logically connected machines	Group of distinct independent computers	Imaginary unlimited space	Fully connected information space
Network	Fast LAN	WAN	Limitless WAN	VWAN
Ownership	Single administration	Multiple parties in multiple location	Single party with many admin domains	Many admin domains
Nodes	Dedicated	Dedicated or Shared	Shared	Shared
Operating System	Homogeneous	Heterogeneous	Heterogeneous	Heterogeneous
Memory Access	Centralized Shared Memory	Distributed Global Memory	Distributed Internet Servers	Centralized Mobile Network Services
Data Sharing	Fine grained	Coarse grained	Fine grained	Fine grained
Coupling	Tightly coupled	Loosely coupled	Tightly or loosely coupled	Loosely coupled
Virtualization	Simple abstraction	Partly abstraction	Full abstraction	Less abstraction
Storage	Higher	Highest	Unlimited storage space	High
Data Security	Highest	High	Higher	Less
Web Familiarity	Less	Moderate	Most	More
Programming	Easier to program	Easy to program	Critical to program	Hard to program
Task execution	All nodes perform a single task by same application	Run different applications independently	Run multiple applications	Run multiple applications
Failure Recovery	Faster	Fastest	Unpredictably Fastest	Fast
Communication	Fast	Faster	Unlimitedly Fastest	Fastest
Availability	High	Higher	Highest	Low
Scalability	Limited scalability	Highly scalable	Limitless scalability	Good scalability
Multitenacy	Low	High	Highest	Higher
Bandwidth	High	Higher	Highest	Low
Latency	Low	Lower	Lowest	High
Noise	High	Low	Lowest	Lower
Cost	High	Moderate	Cheaper	Cheap
End user	Hard to use	Difficult to use	Easier to use	Easy to use

V. REFERENCES

[1] S. Singh and J. F. Kurose, Electing "good" leaders, *Journal of Parallel and Distributed Computing,* Vol. 21, No. 2, May 1994, pp 184-201.

[2] B. Schroeder and G. A. Gibson, A large-scale study of failures in high- performance computing systems, *Proc. of the International Conference on Dependable Systems and Networks,* 25-28 June 2006, pp 249-258.

[3] I. Ahmad, Cluster Computing: A glance at recent events, *IEEE Concurrency*, Vol. 8, No. 1, Jan-Mar 2000, pp 67-69.

[4] J. Liu and P. Wyckoff et.al., Performance Comparison of High-Speed Cluster Interconnects, *IEEE Micro Journal*, Vol. 24, No. 1, Jan 2004, pp 42-51.

[5] A. Coates and et.al., Deep learning with COTS HPC systems, *Journal of Machine Learning Research*, Vol. 28, No.3, May 2013, pp 1337-1345.

[6] A. Wiekens, A Prospect on High Performance Computing, *3rd Twente Student Conference on IT*, 20 June 2005, pp 1-6.

[7] Y. Huang, H. Su, W. Sun, J. M. Zhang, C. J. Guo, M. J. Xu, B. Z. Jiang, S. X. Yang, and J. Zhu, Framework for building a low-cost,scalable, and secured platform for Web-delivered business services, *IBM Journal of Research and Development*, Vol. 54, No. 6, Nov 2010, pp.535-548.

[8] Y. M. Teo and R. Ayani, Comparison of Load Balancing Strategies on Cluster- based Web Servers, I*nternational journal on SIMULATION*, Nov. 2001, Vol. 77, No.5-6, pp 185-195.

[9] K. Keahey, M. Tsugawa, A. Matsunaga, and J. Fortes, Sky Computing, *IEEE Internet Computing Magazine*, Vol. 13, No. 5, Sept 2009,pp. 43-51.

[10] R. K. Buyya, High Performance Cluster Computing: Systems and Architectures, Vol.1, Prentice Hall PTR, New Jersey, USA 1999.

[11] R. K. Buyya, High Performance Cluster

[12] S. Srivastava, P. Dadheech and M. Beniwal , Load Balancing using High Performance Computing Cluster Programming , *IJCSI International Journal of Computer Science Issues*, Vol. 8, No. 1, Jan 2011 , pp 62 -66.

[13] M. Tripathy and C.R. Tripathy, A Review on Literature Survey of Clusters, *International Journal of Advances in Engineering & Technology*, Vol.5, No.2, Jan 2013, pp. 381-398.

[14] P. Morilloa and A. Bierbaumb et.al., Analyzing the performance of a cluster-based architecture for immersive visualization systems, *Journal of Parallel and Distributed Computing*, Vol.68, No.2, 2008, pp 221 – 234.

[15] M Tripathy and C.R. Tripathy, Design and analysis of a Dynamically Reconfigurable Shared Memory Cluster, *International Journal of Computer Science and network Security*, Vol.10, No.9, Sept 2010, pp 145-158.

[16] X. M. Huang, C. Y. Chang and M. S. Chen, Peer Cluster: A Cluster- Based Peer-to-Peer System, *IEEE Transactions on Parallel and Distributed Systems*, Oct. 2006, Vol. 17, No. 10, pp 1110 – 1123.

[17] M Tripathy and C.R. Tripathy, On A Virtual Shared Memory Cluster System with Virtual Machines, *International Journal of Computer and Electrical Engineering* , Vol. 3, No. 6, Dec 2011, pp 754-761.

[18] M. Aldinucci, M, Danelutto et.al., VirtuaLinux: Virtualized High Density Clusters with no single point of failure, *Proc. of the International Conference on Parallel Computing: Architectures, Algorithms and Applications*, 4-7 Sept 2007, pp 355-362.

[19] H. Gao and Y. Zhai, System Design of Cloud Computing Based on Mobile Learning, *Proc. of the 3rd International Symposium on Knowledge Acquisition and Modeling*, Nov. 2010, pp. 293 - 242.

[20] C. Kobhio, S. Pierre and A. Quintero, Redundancy Schemes for High Availability Computer Clusters, *Journal of Computer Science*, Vol. 2, No. 1, Jan 2006, pp 33-47.

[21] Y. M. Teo and R. Ayani, Comparison of Load Balancing Strategies on Cluster- based Web Servers, *International journal on Simulation*, Nov. 2001, Vol. 77, No.5-6, pp 185-195.

[22] R. L.Graham and S. F. Choi et.al., A network-failure-tolerant message-passing system for terascale clusters, *International Journal of Parallel Programming*, Vol. 31, No. 4, Aug 2003, pp 285 – 303.

[23] H. Zhang, On Load Balancing Model for Cluster Computers, *IJCSNS International Journal of Computer Science and Network Security*, Vol. 8, No. 10, Oct 2008, pp 1590-1602.

[24] C. S. Yeo and R. K. Buyya, Managing Risk of Inaccurate Runtime Estimates for deadline constrained job admission controls in clusters, *Proc. of the International Conference on Parallel Processing*, 14-18 Aug. 2006, pp 451 – 458.

[25] C. Leangsuksun and L. Shen et.al., Availability Prediction and Modeling of High Availability OSCAR Cluster, *Proc. of 5th IEEE International Conference on Cluster Computing*, 01-04 Dec 2003, pp 380-386.

Computing: Programming and Applications, Vol.2, Prentice Hall PTR, New Jersey, U

[26] C. J. Lai and W. Polak, A Collaborative Approach to Stochastic Load Balancing with Networked queues of autonomous service clusters, Proc. *of 2nd IEEE Collaborative Computing Conference*, 17-20 Nov. 2006, pp 1-8.

[27] G. Pfister, In Search of Clusters, Prentice Hall PTR, New Jersy, 1998.

[28] C.S.R. Prabhu, Grid and Cluster Computing, Prentice Hall Of India Pvt. Ltd., 2008.

[29] H.A. Sanjay and S. Vadhiyar, Performance modeling of parallel applications for grid scheduling, *Journal of Parallel and Distributed Computing*, Vol. 68, No. 8, Aug 2008, pp 1135–1145.

[30] M. Bertier, L. Arantes and P. Sens, Distributed mutual exclusion algorithms for grid applications: A hierarchical approach, *Journal of Parallel and Distributed Computing*, Vol. 66, No.1, Jan 2006, pp 128 – 144.

[31] A. Katsifodimos, G. Pallis and M. D. Dikaiakos, Harvesting Large-Scale Grids for Software Resources, *Proc. of 9th IEEE/ACM International Symposium on Cluster Computing and the Grid*, 18-21 May 2009, pp 252-259.

[32] A. Singh , An Efficient load balancing algorithm for Grid Computing using Mobile Agent, International *Journal of Engineering Science and Technology*, Vol. 3 No. 6, June 2011, pp 4744- 4748.

[33] M. Taufer and T. Stricker et.al., On the Migration of the Scientific Code Dyana from SMPs to Clusters of PCs and on to the Grid, *Proc. of 2nd IEEE/ACM International Symposium on Cluster Computing and the Grid*, 21-24 May 2002, pp 93– 101.

[34] J. Li, Grid resource discovery based on semantically linked virtual organizations, *Future Generation Computer Systems*, Vol. 26, No.3, Mar 2010, pp 361-373.

[35] S. Adabala and V. Chadha et.al., From virtualized resources to virtual computing grids: the In-VIGO system, *Future Generation Computer Systems*, Vol. 21, No. 6, June 2005, pp 896–909.

[36] C.L. Lai and C.T. Yang, Construct a Grid Computing Environment on Multiple Linux PC Clusters, *Tunghai Science* Vol. 5, July 2003, pp 107−124.

[37] D. Laforenza, Programming High Performance Applications in Grid Environments, *Proc. of First IEEE International Symposium on*

Cluster Computing and the Grid, 15-18 May 2001, pp 10-11.

[38] A. Kushwah, R. Gupta and G. Singh, Cloud Computing: A New Aspect of Technology, *International Journal of Computer Technology and Electronics Engineering*, Vol 2, No. 4, Aug 2012, pp 37-40.

[39] C. Vecchiola, X. Chu, and R. Buyya, Aneka: A Software Platform for NET-Based Cloud Computing, *Journal on Computing Research Repository*, July 2009, pp. 267 - 295.

[40] R. Buyya, C. S. Yeo, S. Venugopal, J. Broberg, and I. Brandic, Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility, *Journal on Future Generation Computer Systems*, Vol. 25, No. 6, June 2009, pp. 599 - 616.

[41] I. Gandotra, P. Abrol, P. Gupta, R. Uppal and S. Singh, Cloud Computing Over Cluster, Grid Computing: a Comparative Analysis, *Journal of Grid and Distributed Computing*, Vol. 1, No. 1, Dec.2011, pp 01-04.

[42] R. Buyya, K. Sukumar, Platforms for Building and Deploying Applications for Cloud Computing, *CSI Communications*, Vol.35, No. 1, Apr 2011, pp 6-11.

[43] W. Tsai, X. Sun, and J. Balasooriya, Service-Oriented Cloud Computing Architecture, *Proc. of the 7th Int. Conference on Information Technology: New Generations*, 12-14 Apr 2010, pp. 684-689.

[44] S. Majumdar, Resource Management on Clouds: Handling Uncertainties in Parameters and Policies, *CSI Communications*, Vol.35, No. 2, May 2011,pp 16-19.

[45] G. H. Forman and J. Zahorjan, The Challenges of Mobile Computing, *IEEE Computer Society Magazine*, Vol.27, No. 4, Apr 1994, pp 38-47.

[46] M. R. Lee, and T. Chen, Trends in Ubiquitous Multimedia Computing, *International Journal of Multimedia and Ubiquitous Engineering*, Vol. 4, No. 2, Apr, 2009,115-124.

[47] G. Bell and P. Dourish, Yesterday's tomorrow:notes on ubiquitous computing's dominant vision, *Journal of Personal and Ubiquitous Computing*, Vol. 11, No. 2, Jan 2007, pp 133-143.

[48]T. Kindberg and J. Barton, A Web-Based Nomadic Computing System, *Internet and Mobile Systems Laboratory*, Version of July 10, 2000, pp 1-13.

[49] J. H. Christensen, Using RESTful web-services and cloud computing to create next generation mobile applications, *Proc. of the 24th ACM SIGPLAN conference companion on Object oriented programming systems languages and applications*, 25-29 Oct 2009, pp. 627-634.

[50] K. Kumar and Y. Lu, Cloud Computing for Mobile Users: Can Offloading Computation Save Energy, *IEEE Computer Society*, Vol. 43, No. 4, Apr 2010, pp 51-56.

[51] P. Papakos, L. Capra, and D. S. Rosenblum, VOLARE: context-aware adaptive cloud service discovery for mobile systems, *Proc. of the 9th Int. Workshop on Adaptive and Reflective Middleware*, Nov. 2010, pp. 32-38.

[52] J. Shen, S. Yan, and X-S. Hua, The e-recall environment for cloud based mobile rich media data management, *Proc. of the 2010 ACM multimedia workshop on Mobile cloud media computing*, 25-29 Oct. 2010, pp. 31-34.

[53] B. G. Chun, S. Ihm, P. Maniatis,M. Naik, and A. Patti, CloneCloud: elastic execution between mobile device and cloud, *Proc. of the 6th conference on Computer systems*, 10 Apr 2011, pp. 301-314.

[54] M. Satyanarayanan, P. Bahl, R. Caceres, and N. Davies, The Case for VM-Based Cloudlets in Mobile Computing, *IEEE Pervasive Computing*, Vol. 8, No. 4, Oct. 2009, pp. 14-23.

[55] Y. Dong, J. Peng, D. Wang, H. Zhu, F. Wang, Sun C. Chan, and Michael P. Mesnier, RFS: a network file system for mobile devices and the cloud, *ACM SIGOPS Operating Systems Review*, Vol. 45, No. 1, Jan 2011,pp. 101-111.

[56] www.wikipedia.org

[57] http://www.topclusters.org

[58] http://www.buyya.com/cluster

[59] http://www.ieeexplore.ieee.org/

[60] http://www.ccgrid.org

[61] http://www.internet.com

[62] http://www.research.nokia.com

[63] http://www.mobilecloudcomputingforum.com

[64] http://www.cloudcomputingapps.org

[65] http://www.tutorialspoint.com/listtutorials/mobile-computing

[66]www.wikipedia.org/wiki/Personal_Communications_Service

[67]www.oecd-ilibrary.org/mobile-and-pstn-communication-services

[68] www.redbooks.ibm.com/redbooks

[69] www.cloudbus.org/intergrid/reports/intergrid_case.pdf

[70] www.webopedia.com/TERM/P/private_cloud

[71] www.vmware.com/in/cloud-computing/public-cloud

[72]www.cloudtweaks.com

[73]www.rackspace.com/cloud/hybrid

[74] www.wikipedia.org/wiki/Software_as_a_service

[75] www.wikipedia.org/wiki/Platform_as_a_service

[76] www.softlayer.com/Cloud

[77] www.wikipedia.org/wiki/Network_as_a_service

[78]www.wikipedia.org/wiki/cloud