Virtualization in Cloud Computing : Developments and Trends

Isaac Odun-Ayo
Covenant University, Nigeria
isaac.odun-ayo@covenantuniversity.edu.ng

Olasupo Ajayi
University of Lagos Nigeria
olaajayi@unilag.edu.ng

Chinonso Okereke
Covenant University, Nigeria
chinonso.okereke@covenantuniversity.edu.ng

***Abstract*—Cloud computing is an interesting paradigm that is making computing and other related activities easy for consumers. The cloud infrastructure is not new, but it is working on new technology based on various services offered. The cloud provides application software online for users to conduct common activities like word processing. Cloud computing also enables consumers to leverage on cloud infrastructure by designing and deploying their application on the cloud. A unique feature of the cloud is the provision of scalable storage for data which are usually spread across several geographical locations. A core technology used on the cloud is virtualization. This allows virtual machines to be hosted on physical servers. This provides great benefits to users on the cloud. This paper presents the state of the art from some literature available on cloud virtualisation. The study was executed by means of review of some literature available on cloud virtualisation. The study was performed by means of review of some literature using reliable methods. This paper examines present trends in the area of cloud virtualisation and provides a guide for future research. In the present work, the objective is to answer the following question: what is the current trend and development in cloud virtualisation? Papers published in journals, conferences, white papers and those published in reputable magazines were analysed. The expected result at the end of this review is the identification of trends in cloud virtualisation. This will be of benefit to prospective cloud users and even cloud providers.**

Keywords-Cloud computing; Virtualization; Applications; Virtual Machines

I. INTRODUCTION

"Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" [1]. Cloud computing is dynamically changing the way IT activities are conducted in organizations and enterprises alike. It is also enhancing IT technological developments as new technologies emerged regularly to improve the way IT activities are conducted. Cloud computing offers unique features such as elasticity, scalability, multi-ternary, resource pooling that makes it attractive to IT users [2]. Cloud computing has three basic service types, the Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS). In SaaS the cloud provider offers applications for use to cloud users at a fee over the internet. The user does not need to buy a license or install an application before using it. In PaaS the cloud provider offers the cloud uses an environment for creating and deploying an application through interfaces provided. The cloud user has control over the application deployed while the cloud provider controls the infrastructure. In IaaS, the cloud provider offers infrastructure for computing and storage to the cloud user. The resources are available on demand and at a cost. The cloud user has control over the operating system and applications, while the cloud provider controls the resources. Cloud computing offers four deployment types; private cloud, public cloud, community and hybrid clouds. The private cloud infrastructure is owned by an organization using internal staff of the organization. The facility can be off-premise or on-premise and it is considered more secure. The public cloud is owned by the major cloud service providers. They have huge infrastructures and data centres spanning different geographical locations. They are usually considered less secure. Community cloud is formed by several organizations with shared common interest. The cloud is either managed by the community or a third party. Hybrid cloud is a combination of either private, public or hybrid cloud, taking advantage of the benefits of cloud computing. They remain unique entities, but are bound by technology and managed by a single unit.

Virtualization is a core concept in cloud computing. Most of the activities on the cloud are centred on virtualization technology. Virtualization technology involves the creation of a virtual version of operating system, a server, a storage device or network resources [3]. Virtualization technology enables a single machine to run multiple platforms concurrently, for example different versions of windows running at the same time on a single machine. Sometimes referred to as machine or processor virtualization, it allows a single physical machine to emulate the behaviour of multiple machines, with the ability to host multiple/heterogeneous operating system on the same hardware [4]. The hosted operating systems are called guest operating systems. Virtualization allows for server consolidation in data centres, where multiple operating systems that would have been underutilized on their host to be moved to the same physical resources. This enables a reduction in the number of physical machines and their improved exploitation at higher saturation levels thus saving cost and energy [4]. Virtualization can be seen as using computer resources to imitate other computer resources or whole computer. [10]. It separates resources

and services from the underlining physical delivery environment.

The purpose of this paper is to examine the concept of virtualization in relation to cloud computing. Various area of virtualization will be discussed and thereafter current trend in industry will be highlighted. This paper will contribute to better understanding of virtualization and development trend in the industry. The rest of the paper is as follows. Section 2 examines related work. Section 3 discusses the benefits and types of virtualization. Section 4 highlights current trends in the industry. Section 5 concludes and suggests future work.

II. Related Work

In [6], Security in Cloud Computing: Opportunities and Challenges is proposed. The main focus is on general security on the cloud. The paper also discussed virtual network and virtualization issues. In [7], Identifying Cloud Security Threats to Strengthen Cloud Computing Adoption Framework is presented. The approach was to examine security issues that could affect cloud migration. It also discussed some aspects of virtualization. In [8], Secure Virtualization for Cloud Environment Using Hypervisor-based Technology is proposed. The paper discusses virtualization technology in terms of security on the cloud. A model is proposed based on the hypervisor to ensure security in the cloud. In [5], Cloud Computing: Types, Architecture, Applications, Concerns, Virtualization and Role of IT Governance in Cloud is presented. The approach was to discuss various issues relating to cloud computing. It also briefly examined aspects of virtualization. In [9], KVM & OpenVZ virtualization based IaaS Open Source Cloud Virtualization Platforms: OpenNode, Proxmox VE is proposed. An open source virtualisation concept is discussed. Various virtualization concepts are discussed and thereafter two open source IaaS systems are analysed. In [2], Dynamic Resource Allocation using Virtual Machines for Cloud Computing Environment is presented. Virtualization allows the dynamic allocation of cloud resources on demand by optimum utilization of server. The concept of skewness was further introduced to enhance exploitation of servers. In [10], The Xenon Separation VMM: Secure Virtualization Infrastructure for Military Clouds is presented. The approach is to introduce the concept of the separation VMM in place of separation kernels. This provides the adequate separation of cloud VMs.

In [3], an overview of virtual machine placement schemes in cloud computing is presented. This focuses on the concept of virtual machine migration for cloud service providers. The paper conducts a survey of VM placements in data centres, stating advantages and limitations also. In [11], A Survey of Virtual Machine Placement Techniques in a Cloud Data centre is proposed. Energy consumption is an issue in data centres as regards virtualization. The approach is also using VM placement techniques to for optimum energy consumption. In [12], Challenges in real-time virtualization and predictable cloud computing is proposed. The paper addresses the issues related to virtualization and emerging applications. Challenges related to current real-time virtualization is examined to enable utilization of real time applications. 1n [12], Cloud computing and virtualization technology in radiology is presented. The paper discusses the concept of virtualization and how it is utilized in radiology. In [13], Effects of virtualization on information security is presented. The paper discusses virtualization technology and carried out a survey on system security. The outcome shows that virtualisation is beneficial to cloud security in certain sectors.

III. Benefits, Techniques and Issues in Virtualization

A. Characteristics and Application of Virtualization

Virtualization has three characteristics and various applications as discussed [5]:

1) Partitioning

In virtualization, many applications and operating systems are supported in a single physical system by partitioning the available resources.

2) Isolation

Each virtual machine is isolated from its host physical system and other virtualized machines. Based on this isolation, if one virtual machine crashes, it does not affect the other virtual machines. In addition, data is not shared between virtual machines.

3) Encapsulation

A virtual machine can be represented and even stored as a single file, so it can be identified easily based on the services it provides. The encapsulated process can be a business service. Encapsulation prevents interference among applications. Virtualization has application in several areas such as memory, networks, storage, hardware, operating systems and application. Virtualization is unique for cloud computing because it decouples the software from the hardware. Decoupling means that software is put in a separate container so that it's isolated from operating systems.

B. Benefits of Virtualization

Virtualization technology offers applications an abstract view through interfaces of the underlying hardware platform and resources with the following benefits [4].

1) Functional Execution Isolation

The hyper visor handles the protection among virtual machines (VMs) and therefore among the applications on different VMs. Users can be granted privileges within their VM without compromising the isolation or host integrity.

2) Customized Environment

Virtualization enables the provisioning of a highly customized and specialized environment that may contain specific purpose operating systems, libraries, and run time environments. Virtualization offers multiple views over the same physical hardware through functional isolation.

3) Easier Management

Customized run-time environment can be started-up, migrated, shutdown in a very flexible way depending on the need of who provides the underlying hardware.

4) Coexistence With Legacy Application

Legacy applications can coexist with brand new ones. VMs help to preserve binary compatibility in the run-time environment for legacy applications.

5) Testing and Debugging Parallel Apps

Testing parallel applications can leverage virtualized environments, as a full distribute system may be emulated within a single physical host.

6) Enhance Reliability.

Hypervisors and their live migration capabilities allow for enhanced reliability of hosted virtualized applications. This makes them independent of the reliability of the underlying hardware in a seamless and transparent manner for applications.

C. VM Migration [4][9]

VM migration is an interesting feature of cloud computing which is aimed to respond to dynamic requests of VMs in order to guarantee the promised SLA to the cloud consumer. Thus when VM request for some resources which cannot be provided in the hosted physical machine, the VM is migrated to another physical machine to satisfy the VMs requested resource. Also VMs may be migrated to provide better management of the physical machines and data centres. One of the most important operations which is conducted as part of the VM migration is the VM placement in which a proper physical machine is selected to host the VM.

D. Virtualization Types

There are nine types of virtualization [4] [8] [9] [12]

1) Full Virtualization

Full virtualization runs any non-modified operating system which supports the platform being emulated. The main disadvantages of emulations are low performance and low density. Examples are Microsoft Hyper-V, VMware Workstation.

2) Hardware Assisted Virtualization

This provides architectural support that facilitates building a virtual machine monitor and allows guest OS, to be run in isolation. Examples are Xen, KWM Microsoft Hyper-V.

3) Partial Virtualization

In this case, some but not whole target environment is simulated. The virtual machine simulates multiple instances of much of an underlying hardware environment particularly address spaces and each virtual machine consist of an independent address space. Some guest programs, therefore may need modification. Example IBMCP/CMS.

4) Paravirtualization – OS Assisted Virtualization

This runs multiple modified OSs on top of a thin layer called hypervisor, or virtual machine monitor. Paravirtualization has better performance compared to emulations, but the guest OS needs to be modified.

5) Operating System Level Virtualization

This is a multiple isolated execution environment within a single operating system. It has the best possible performance and density and features dynamic resource management. On the other hand, this resource does not allow the running of different kernels from different OSs at a time E.g. OpenVZ, Solaris. An Operating system-based Virtualization is at Fig. 1.

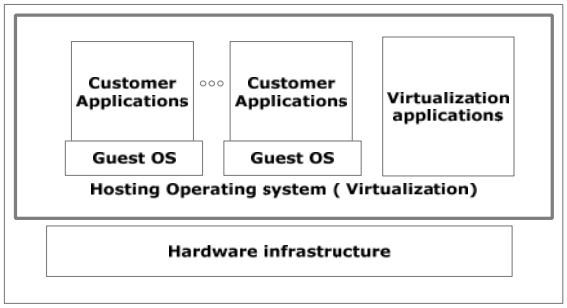


Figure. 1 Operating System-Based Virtualization

6) Multi-server Cluster Virtualization

This is making very large group of servers appear and act like a single system, and easy to manage as a single workstation. Cluster virtualization is the most cost effective method for reducing the complexity, cost and overall administrative burden of large scale computing, enabling providers to get the most of computing resources.

7) Hypervisor-Based Virtualization

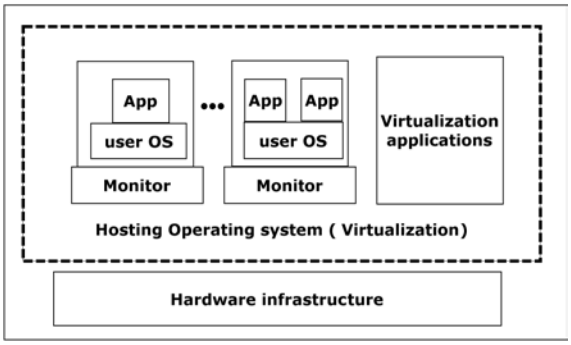
The hypervisor is available at the boot time of the machine in order to support the sharing of resources across multiple VMs. Some of those VMs are privileged operations which manage the virtualization platform and hosted virtual machines. This technique establishes the most controllable environment and utilizes additional securing tools such as intrusion detection system. However, it is vulnerable because the hypervisor has a single point of failure. If the hypervisor crashes or is attacked, all the VMS will be compromised. This is shown in Fig. 2a and b.

8) The Application Level Virtualization [4].

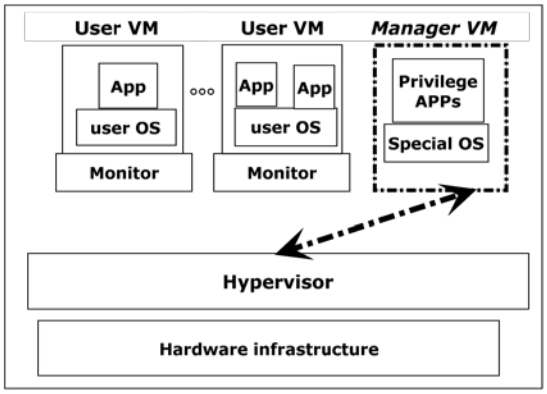
Application level or process – level virtualization is a software technique allowing an application to be developed for, and run on top of a virtual instruction set which is independent of the actual underlying hardware. A special software programme is capable of interpreting at run time such instruction, executing them on real hardware. This applies to Java and .Net applications.

9) Network Virtualization

Network virtualization allows the emulation of network set up in software. They are useful for allowing multiple VMs to run the same physical host, with their own IP address, connected together in a virtual bridge topology.



(b) Application-based Virtualization



(c) Hypervisor-based Virtualization

Figure. 2. Application level virtualization and Hypervisor-Based Virtualization [8]

IV. INDUSTRY TRENDS IN VIRTUALIZATION

A. *Container Technology*

Containerization is a virtualization method that exists on the OS level rather than at the hardware level where traditional server virtualization occurs. Containers are isolated environments that share single OS kernel, so they move across hosts and platforms more easily than virtual machines. At the moment cloud containers are hot topics in the IT world and container technology is everywhere and constantly evolving. Containers promise a streamlined easy to deploy and secure method of implementing specific infrastructure requirements and they also offer an alternative to virtual machines [computer world]. Cloud containers are designed to virtualize a single application. For example if a user has a MySQL container and that is all it does, provide a virtual instance of that application. Containers create an isolation boundary at the application level rather than the at the server level. This isolated means that if anything goes wrong in that single container for example, excessive consumption of resources by a process, it only affects that individual container and not the whole VM or whole server. It also stop compatibility problem between applications that reside in the same operating system. So far cloud containers have predominantly been the domain of Linux – based servers, Microsoft is also introducing Hyper-V containers to be integrated in the Microsoft Azure.

1) Differences between a Container and a Virtual Machine

The key differentiation with containers is the minimalist nature of their deployment. Unlike virtual machines, containers do not require an OS to be installed within the container, and they do not need a virtual copy of the host server hardware. Containers are able to operate with minimum resources to perform the task they were designed for, using a few software, libraries and the basics of an OS. This results in two or three times as many containers being able to deploy on a server than virtual machines. Cloud containers are also very portable, once they have been created, it can be deployed to different servers very easily. From a software life cycle perspective this is excellent, as containers can be copied to create development, test integration and live environments quickly, and do not require the usual configuration. From a software and security perspective, this has a large advantage, because it ensures that the underlying OS is not causing a difference in the test result.

However, containers have the disadvantage of splitting virtualization into lots of small bits. When there are just few containers involved, it is good, because the user knows what configuration is being deployed and where. However, lots of containers are difficult to manage. Virtual machines are generally considered easy to manage, primarily because they are usually fewer compared to containers. Containers can be deployed by either creating an image to run in a container or by downloading a pre–created image such as from Dock Hub.

2) Container Development Project

- Open container initiative: The Linux foundation designed the Open Container Initiative (OCI) to establish common standard for container virtualization technologies.
- Linux container project: This project is built and designed as a distributors and vendors neutral environment, which aims to develop Linux containers.
- Linux container Hypervisor: This is a canonical-founded and Apache 2 licensed open source project that acts as a set of tools for container deployment, management and security.
- Docker: This is an open source program that enables developers to package Linux application and their dependencies as containers.
- Advanced Program–to–Program Communication: This is an open standard communication protocol and programming interface supported on most platform

3) Network Virtualization

Presently, there are other growing paradigms such as the software – define network (SDN) and network

virtualization. In SDN, and specifically hardware–centric implementation of the SDN model, software takes direct control of physical switches by directly programming the virtual and physical switches. A hardware-centric approach typically requires upgrading physical switches, so it's both disruptive and expensive.

V. CONCLUSION

Cloud computing provides compute, storage and application services among others to users over the Internet. The resources made available to users by CSPs has reduced the need for expenditures on infrastructure. The Cloud is used for numerous activities but prominent among them are computation and storage. This paper focused on Cloud storage. A review of Cloud storage systems, architecture, models and challenges was done. A comparison of some of the storage features offered by two popular Cloud Storage Service Providers IBM and Amazon was also done. In conclusion it is important to note that despite certain Cloud challenges particularly in terms of security and privacy, Cloud storage is still being adopted at a tremendous rate; and research works are still on-going in a bid to further push the boundaries of Cloud storage adaptation.

REFERENCES

[1] Peter Mell, Timothy Grance, (2011) "The NIST Definition of Cloud Computing", NIST Special Publication 800-145

[2] Zhen Xiao, Weijia Song, Qi Chen, (2013), "Dynamic Resource Allocation using Virtual Machines for Cloud Computing Environment", IEEE Transaction On Parallel And Distributed Systems. Vol. 24, No. 6 Year 2013

[3] Mohammad Masdari, Sayyid Shahab Nabavi, Vafa Ahmadi, (2016), "An overview of virtual machine placement schemes in cloud computing", Journal of Network and Computer Applications 66 (2016) 106–127.

[4] Marisol García-Valls, Tommaso Cucinotta, Chenyang Lu, (2014), "Challenges in real-time virtualization and predictable cloud computing", Journal of Systems Architecture 60 (2014) 726–74

[5] Pankaj Sareen, (2013), "Cloud Computing: Types, Architecture, Applications, Concerns, Virtualization and Role of IT Governance in Cloud", International Journal of Advanced Research in Computer Science and Software Engineering, Volume 3, Issue 3, March 2013 ISSN: 2277 128X

[6] Mazhar Ali, Samee U. Khan, Athanasios V. Vasilakos, (2015), "Security in Cloud Computing: Opportunities and Challenges", Information Sciences 305 (2015) 357-383.

[7] Nabeel Khan, Adil Al-Yasiri, (2016), "Identifying Cloud Security Threats to Strengthen Cloud Computing Adoption Framework", The 2nd International Workshop on Internet of Thing: Networking Applications and Technologies (IoTNAT' 2016).

[8] Farzad Sabahi, (2012), "Secure Virtualization for Cloud Environment Using Hypervisor-based Technology", International Journal of Machine Learning and Computing, Vol. 2, No. 1, February 2012.

[9] Kovari A, P. Dukan, "KVM & OpenVZ virtualization based IaaS Open Source Cloud Virtualization Platforms: OpenNode, Proxmox VE", Access on 24 May 2017

[10] McDermott J, Saguy, B. Montrose, M. Li, J. Kirby, M. Kang, "The Xenon Separation VMM: Secure Virtualization Infrastructure for Military Clouds", Naval Research Laboratory Center for High Assurance Computer Systems, Washington.

[11] Zoha Usmani, Shailendra Singh, (2016), "A Survey of Virtual Machine Placement Techniques in a Cloud Data Center", International Conference on Information Security & Privacy (ICISP2015), 11-12 December 2015, Nagpur, INDIA. Procedia Computer Science 78 (2016) 491 – 498.

[12] Patel R.P, (2012), "Cloud computing and virtualization technology in radiology", Clinical Radiology 67 (2012) 1095 - 1100.

[13] Shing-Han Li, David C. Yen, Shih-Chih Chen, Patrick S. Chen, Wen-Hui Lu, Chien-Chuan Cho, (2015), "Effects of virtualization on information security", Computer Standards & Interfaces 42 (2015)-8

[14] Emily Mell (2016) 'Cloud containers -- what they are and how they work', TechTarget Publication, ComputerWorld

[15] Emily Mell (2016) 'Words to Go: Virtual container standards', TechTarget Publication, ComputerWorld