Cloud Computing and Open Source Software: Issues and Developments

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***Abstract*—Cloud computing is a global paradigm that is offering useful services in virtually all spheres of human endeavor based on infrastructure made available to users on demand. The cloud provides on demand, elastic and scalable resources to meet the needs of users. The cloud has application deployed by cloud service providers that can be accessed by several users at the same time. Cloud computing also offers a programming environment that allows users deploy and run their own in-house applications. Massive storage and computing resources are also available on the cloud. There are currently open source applications that can be used to implement cloud applications. The source code which can be improved on and adapted for use is available to the user online. Such open source software tools allow the deployment of cloud for any type of domain. The study was executed by means of review of some literature available on cloud computing and open source software. This paper examines present trends in cloud computing and open source software 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 computing and open source software? The review's finding is that OpenStack provides the most comprehensive infrastructure in cloud computing and open source software.**

***Index Terms*— Cloud, Cloud application, Cloud Computing, Open source software**

I. INTRODUCTION

"CLOUD computing is a tool that enables convenient and on-demand network access to a large pool of systems that is connected through public or private networks which provides dynamic infrastructure for applications and data storage" [1]. The codes of an open source software is available for anyone one to use, make changes and also amend to suit a user's specific needs. Open Source Software (OSS) is a new paradigm used to develop software by a community, in which groups of developer collaborate with each other [2]. The processes for the release of an open source software is unique because the source code, and all relevant information are available for anyone to access at anytime, which makes the OSS project a worthwhile one. Cloud computing is making great impact in all facets of life bringing useful benefits to cloud service providers and cloud users alike. Cloud computing offers on demand, reliable, scalable and elastic services to cloud users. There are three primary types of services offered in cloud computing Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS), and Infrastructure-as-a-Service (IaaS). In SaaS, useful productivity applications are offered to cloud users at a fee over the Internet. Cloud users do not have to worry about installation and licenses and the application can be accessed anytime anywhere using suitable devices. In PaaS, the cloud user has the opportunity of leveraging on the CSP platform to create and deploy custom applications. The user has control over his application and the operating system while the CSP controls of the underlying infrastructure. In IaaS, the CSP provides compute resource and storage capacity, such CSPs have large infrastructure spread across different geographical locations. The user has control over the compute resource and storage including any deployed application, while the CSP has control over the core infrastructure. Cloud computing offer four deployment types, private, public, community and hybrid clouds. Private clouds are owned by an enterprise and utilized by only in-house staff. The cloud can be hosted on-premise or by a third party and private clouds are considered more secured. Public clouds are owned by large CSPs and they have the infrastructure to provide a wide range of services to organizations and individuals over the Internet. They are considered less secured. Community clouds involves several organizations with shared common interest sharing cloud infrastructure. They are similar to private cloud. Hybrid cloud is a combination of either the private, public or community clouds. Hybrid cloud leverages on the advantages of the different cloud types. Less essential operations can be migrated to public clouds while core activities remain on private clouds in an organization.

Open Source Software is the result of a process that bring highly skilled persons together for the purpose of producing software and applications that is free for public utilization. These activities are often called OSS projects which include source code, documentation of software and test results [3]. In many OSS projects, the products are published under open license and can be accessed freely by anyone. The

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technique for the development of OSS is such that anyone can participate in the design, coding, testing and the documentation process of the OSS. In effect, the process is open to interested persons and the products are also open and available on repositories on the Internet.

Different kinds of OSS projects exist which includes operating systems, libraries and frameworks and application programs [3]. The size of the project in OSS vary from one person to several thousands. The status of OSS projects usually varies; hence a project may be obsolete while another is just starting, and another project is commercially being utilized. OSS projects have different licensing polices, hence some projects are released under public domain, while some are released under GNU (GNU's Not Unix) public license. The quality of OSS applications vary from poor to high standard. Due to the fact that OSS projects are open and many people have opportunity to correct the code, it is likely that most defects are usually corrected. Hence, the quality of OSS applications should be higher than those of closed source. There is generally no license fee, hence it is cost effective to adopt OSS software into computer system. However, testing, quality assurance and validation of OSS applications rest on the project team, hence software quality is not guaranteed.

The purpose of this paper is to discuss open source cloud applications. Benefits of OSS will be discussed, while also examining different cloud OSS software and their security. The rest of this paper is as follows: Section 2 examines related work. Section 3 discusses the benefits and types of OSS applications. Section 4 highlight current trends in the industry. Section 5 concluded and suggest future works.

II. Related Works

A study on maturity model of open source software community to estimate the quality of products in [3], discusses open source software. The OSS is available to a large community of developers for coding and other issues. The paper proposes a method for evaluating OSS based on the maturity model. Building an open source cloud environment with auto-scaling resources for executing bioinformatics and biomedical workflows in [4], considers using open source applications on the cloud services in the bioinformatics and biomedical domain. Several issues were discussed including security of the application. Know your open source code in [5], examines open source code visibility. Lack of visibility has affected security issues leading to unfavorable consequences. Open source as the secure alternative: a case study in [6], discusses the utilization of open source software for cloud IaaS. Security issues were examined and the conclusion is that the process is secure. Open source software: determining the real risk posed by vulnerabilities in [7], is concerned about the impact of OSS on organizations. The focus is to ensure that OSS are more secure to avoid the negative impact of attackers. Total cost of ownership for application replatform in open-source SW in [8], focuses on migration from commercial application to OSS by an organization. The issue of cost methods to reduce cost of migration and ensuring a scalable application was examined. User involvement in software development processes in [9], observes that the cost of software development is reducing due to the development of OSS. The paper focuses on the need for more collaborative development to reduce challenges associated with OSS development process. Criteria for evaluation of open source cloud computing solutions in [10], discusses OSS for IaaS. The focus is on evaluating OSS using some established criteria including security concerns. Open source cloud computing platforms in [11], observes that several open source cloud solutions exist. The paper discusses the major types of open solutions for awareness and further research. A survey on open-source cloud computing solutions in [12], examines open source solutions for the cloud. The paper aims to look at the various applications with a view to highlighting the problems. Open source cloud computing tools: a case study with a weather application in [13], examines open source application tools for cloud computing. The tools discussed were implemented in a weather system. OpenStack: toward an open-source solution for cloud computing in [2], examined different IaaS methods in use. The paper aims to assist in development of open source IaaS application based on the OpenStack.

III. Benefits of Cloud Computing and Source Software

A. Characteristics and Benefits of Cloud Computing

The following are the characteristic of cloud computing [14] [15]

- On demand self-service. Cloud facilities such as applications, servers, compute and storage are provided automatically as required by the user without human interactions.
- Broad network access. Consumer can access cloud resources over the internet at any time, from anywhere through different types of platform.
- Resource Pooling. Physical and virtual computing resources are placed on the cloud. However, the user has no control or knowledge of where these resources are located.
- Rapid elasticity. Computing resources can be rapidly and elastically provided and released, these can be done manually or automatically base on consumer demand. The resources appear to be limitless and can be purchased in any quantity at any time.
- Measured service. Cloud resources and services are controlled and monitored by the CSP through a pay-per-use business model. Consumers utilize these resources in a way similar to using electricity, water and gas.
- Multi-tenancy: is a design in which an instance of software application serves various clients. Every client is known as a tenant. A tenant might be given the capacity to tweak some part of the application for example the colour of the user interface or business rules, but be that as it may, they cannot alter the application's code.

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- Scalability. The resources on the cloud is adaptable. Cloud providers can add new nodes and servers to the cloud with minor alterations to the cloud infrastructure and software.
- Reliability. This is accomplished by utilizing various redundant site. High reliability makes the cloud a seamless solution for disaster recovery.
- Economies of scale. With specific end goal to exploit economics of scale, cloud are implemented as extensive as could be expected. Other factors are also put into consideration to reduce the cost such as locating the cloud close to cheap power station and in low cost real estate.
- Cost Effectiveness. Customers are permitted to lease computing resources and buy IT services that match their needs as oppose to investing in complex and expensive computing infrastructure and services. This bring down the cost of IT services for organizations and people
- Customization. A cloud is a reconfigurable domain that can be modified and balanced regarding infrastructure and application, based on the interest of the user.
- Efficient resource utilization. Delivering resources only for whatever length of time that they are required allows for efficient use of resources.
- Maintainability. CSPs, lessen software and hardware weight on the users, because they maintain the entire infrastructure.
- Collaboration. PaaS allows for collaborative work among users inside an organization or among various organizations.
- Virtualization. Users do not have to worry about physical asset in light of the fact that cloud seclude them at the virtual level.
- High performance. Cloud computing provides users with superior computing environment because of great degree of storage and powerful computing resources of the cloud infrastructure.

B. *Benefits of Open Source Software Application*

OSS is considered a more secure and a better alternative in terms of software. This is based a conclusion arrive at form experience of using OSS to host IaaS applications on the cloud. [16]. Some of benefits of open source software are discussed below [11]

1) Price.

By using OSS, a user does not need to pay for proprietary software anymore, just download the OSS and install. There is usually unrestricted access to the source code, enabling modification to suit user requirements.

2) Flexibility

Once installed it is possible to host the OSS application anywhere. This implies that users does not have to put all its information with a major CSP such as Google. A user can detached the software from the host and have control over the data. A good example is using the Zinbra Open Source, web-based SaaS suite of office applications that can be hosted by any managed hosting provider.

3) Efficient System Integration

Efficient integration can be accomplished through utilization of OSS and making it to suite a company's need with little development effort. Enterprises have built on the OSS foundation to automate large number of processes such as account billing, administration, provisioning, maintenance and monitoring activities. Tools such as python programming language, MySQL database, Django application framework and the Ngnix and Apache web servers are being utilized [16].

4) Cheap Enhancements.

Unlike proprietary software, it is possible to modify or enhance OSS in a relatively cheap manner. It is also possible to improve virtualization technologies to enhance scheduling ensuring that one VM does not monopolize host resources. For example, the OpenStack SWIFT object-storage does not have the content delivery network and ability to upload file via FTP or SFTP, but such functionality can easily be added.

5) Mobility

Due to the fact that all OSS systems are web-based, it is easy for people to work from home or on the road. This is one of the many advantages of OSS, without the usual lock-in associated with proprietary providers. It is usually possible to see all the inner workings of the OSS, and also be confident about security. This provides a much better level of confidence than a commercial application. Ubuntu is an OSS used on desk tops and laptops, example is Firefox which is considered more reliable that Microsoft Windows platform. Linux is considered more reliable and more secure than Ms Window as a personal OS.

6) Transparency with No Lock-In

OSS involves publishing code and getting a community of developers to maintain and improve on it. In addition, OSS has to be easily understandable and maintained by many hence the need for transparency. OSS store their data in a simple manner using common databases like MySQL making access to information quite easy. MySQL has a simple structure that allows exchange of data easily between systems hence simplifying the use of OSS. This design is in contrast to proprietary solutions where the vendor's strategy is to make it very hard to have access into data. This makes the user get locked-in, and the CSP can monopolises the addition of helpful services and data analytics with a view to making more money

7) Increased Security

The general opinion of OSS users is that OSS is more secure than their commercial equivalent. Open source applications are public and anyone may scrutinize and attempt to hack them. However, they are rapidly discovered by the OSS community of developers who then release a patch. Proprietary software is closed and exploits are discovered by hacker who take advantage before it leaks and organization that owns the software does the patching which may not be immediate. Evidence from security advisory sites indicate that in general there are many more security issues with closed products than open source products.

8) Open Hypervisor

All the mini-server VMs use Xen, which is an OSS hypervisor or machine monitor designed and developed by

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Dr Ian Prath at the University of Cambridge [16]. The original goal was to run up to 100 full-featured operating systems instances on a single computer or server. Xen protects user's account on the system and it also ensures secure isolation, resource control, and quality of service guarantees.

9) Government and High–Security Concerns

OSS is considered suitable for government and high-security concerns. Recent penetration tests carried out by *Encryption*, a CREST and tiger-certified organization, observed that there were no security warnings in OSS indicating little or no vulnerabilities [16]. The test included attempts to launch attacks on VMs sharing the same host servers and the lacked of observed security breaches on the attacked VMs, validated the suitability of Xen-based Hypervisor layer.

IV. Open Source Software in Cloud Computing

Different solutions exist for the deployment of open source clouds. They include Nimbus XCP, Eucalyptus, OpenNebula and OpenStack among others.

A. Xen Cloud Platform

Xen cloud platform or (XCP) manages storage, VMs and networks on the cloud. XCP is not focused on the overall framework, but on the setup and maintenance. It enables external tools such as Eucalyptus and OpenNebula to better leverage the Xen hypervisor [3]. The XCP is a solution for infrastructure virtualization that provides an abstraction layer between server's hardware and the OS. A Xen hypervisor allows each physical server to run several virtual servers hiding the OS and its applications from the underlying physical server. The XCP solution is used by many cloud providers such as Amazon EC2, Nimbus and Eucalyptus and the XCP architecture is in [7]. XCP basic component is the XCP host, which is a Xen hypervisor-enabled to communicate with other XCP host. Several XCP host can be bound together into an XCP resource pool. A single XCP host from the pool must be setup as the master XCP host, which offers an administrative interface and commands other XCP host.

Optionally, a resource pool may have a shared storage whose objective is to store and export VM images mainly for VM migration, which allows host administrations to place and replace VMs on any XCP host [7]. Xen is more effective than a commercial equivalent such as Virtuozzo because the OS must be explicitly modified to run on Xen [16]. Xen is able to perform better in terms of virtualization and prevents the sharing of memory or processes, and also preventing disruptions by accounts on the system. [16] [7]. Xen also allocates each account on the system own sub-kernel, making it a dedicated machine at an operational OS level. The implication is that disruptions on any account does not affect the operations of other systems.

Xen is an open source infrastructure manager resource for clouds that does not provide the overall architecture for cloud computing, since it does not provide interface to end users to interact with the cloud [17]. However, XCP provides the needed environment for administrators and an API for developers of cloud management systems [17].

B. Eucalyptus

Since its conception, Eucalyptus was developed for use in services compatible with Amazon EC2 cloud. All communication is done through web service standards. Eucalyptus bridges open cloud software with that of enterprises solution [17]. Unlike XCP, Eucalyptus is designed for two different classes of users; the administrator and the client [4]. Administrators are the user that manage the entire cloud, having access to all Eucalyptus features while users can request and make use of VM instances directly from Eucalyptus without the need for administrative intervention [3]. Eucalyptus is focused towards academic research; hence it provides resources for experimental instrumentation and study. Eucalyptus users are able to start, control, access and terminate entire virtual machines [4]. Eucalyptus provides a solution for IaaS, with an API compatible with Amazon EC2. Eucalyptus is also a solution that allows the installation of a private and hybrid cloud infrastructure [6]. The architecture of Eucalyptus comprises four components as shown in [4]. VMs on a node are managed by node controllers (NC) running on the same node, allowing support of different hypervisors. NC are grouped into clusters and managed by cluster controllers (CCs), which gather state information from each NC, schedules client request to individual NCs and manages configuration of private and public networks [17]. At the top of the architecture is the cloud controller (CLC). It processes client request and makes VM placement decisions [17]. The storage controller (Walrus) is a data storage service compatible with Amazon S3, which is responsible for manipulating VM images, delivering them to NCs when a client instantiates a VM [4]

C. Open Nebula

Open nebula is a simple tool that allows for storage, network, virtualization to enable provision of services on a distributed infrastructure [6]. A number of communities are actively using open nebula, some of these are: the European Space Astronomy Centre and the Organization for Nuclear Research (CERN) [3]. Open Nebula is an open source toolkit used to build private, public and hybrid clouds [4]. It is open source under Apache license written in C++; Shell and Ruby [6]. The open nebula architecture in [6] has been designed to be modular in order to allow the integration with many different hypervisors and environments. The physical infrastructure adopts a classical cluster-like architectures, with a front end and a set of host nodes where VMs will execute [6]. There is at least one physical network joining all the cluster nodes with the front-end. The front-end executes the main open nebula processes, while cluster nodes are hypervisor-enabled host that provide resources needed by VMs [6].

Open nebula has three layers: tools, core and drivers. The tools layer contains modules providing functionalities for administrators and client. The command line interface can be used by the administrator to manipulate the infrastructure. The scheduler is responsible for VM placement. The core

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layer consists of components for handling clients' requests and control resources [6]. The main component in this layer is the request manager which handles client request through an XML-RPC (remote procedure call) interface calling the internal components according to the invoked methods. The driver layer supports different underlying platforms. These drivers run on separate processes that communicate with the core module through a simple text messaging protocol [6]. The drivers deal with file transfer, manage VMs and request services from external clouds like Amazon EC2.

D. OpenStack

OpenStack is a platform developed by NASA and dedicated to massive infrastructure. The solution can handle data volumes on petabytes of distributed system and massively scalable up to 1 million physical machines and up to 60 million virtual machine and billions of stored objects. Open stack supports most virtualization solutions in the market such as ESX, Hyper-V, KVM, LXC, QEMU UML Xen and Xen server [6]. It is written in python and currently implements two control APIs: the EC2 API and Rackspace. It appears to be the best solution currently and can become the reference solution for open source cloud computing. OpenStack architecture is built using three main components: open stack compute, image and object. OpenStack compute also known as Nova is a management platform that controls the infrastructure for handling IaaS clouds [6]. Compute requires no prerequisite hardware and is completely independent of the hypervisor. The open stack architecture is at [6]. The open stack image service (Project Glance) provides storage services, recording and distributing the images to virtual machine disks. It also provides APIs compatible with the REST (Representational State Transfer) architecture to perform queries for information on images hosted on different storage system. The OpenStack object storage (Swift Project) is used to create a storage space redundant and scalable for storage of multiple petabytes of data. It is not really a file system but specially designed for long-term storage of large volumes. It uses a distributed architecture with multiple access points to avoid single points of failure.

E. Securing Open Source Software

Until mechanisms are in place to ensure that OSS goes through a thorough review and validation process to minimize security vulnerabilities, there will continue to be uncertain and undiscovered flaws, some of which will prove critical in pieces of codes that are widely distributed [12]. Organizations looking to protect their reputation in the market and guard against exploitation in OSS are utilising the latest available security vulnerability and license data collected by public and private firms [16]. Also, it is not enough to find vulnerabilities during development, many flaws will still be discovered later. Therefore, constant monitoring of OSS is essential. One primary source of OSS security vulnerability information is the National Vulnerability Database (NVD) under the guidance of the NIST [12]. NVD catalogues and present vulnerability information using Security Content Automation Protocol. In 2014, NVD catalogued 11,000 common vulnerability enumerators (CVEs) with 4,300 in open source codes. This translates to 11 CVEs per day. Without an automated system, enterprises lack an easy way to detect and analyse these potential problems. VulDB databases is maintained by Risk Based security as a proprietary database that compliments NVD [16]. It has greater number of entries and a lot of remediating information that are very useful in contending with security risk [12]. Automated systems are better because they combine data from other databases that contain information drawn from crawling and scanning both source codes and binaries for security and compliance issues [12].

V. CONCLUSION

Cloud computing has enabled massive development in hardware and software infrastructure. Cloud computing offers elastic, scalable on-demand services to cloud users via the Internet. Such services are helping to improve operations both for small and big enterprises alike. The developments in cloud computing is also reflected in the advances being made in the area of OSS. OSS is available for the public to use and at the same time contribute to cloud developments. Several OSS are being used to enhance activities on the cloud. Such OSS like OpenStack are providing massive opportunities in cloud computing. However, security vulnerabilities in OSS must continue to receive greater attention.

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