Deploying An OpenStack Cloud Computing Framework for University Campus

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***Abstract*— The cloud computing paradigm is having its moment of glory. A number of enterprises are adopting the cloud computing platform to experience the benefits of self serviced, user guided, rapidly scalable and flexible environment. The time is right for the educational universities also to derive benefits of the cloud as these institutions are obliged to deliver better ubiquitous services to students with existing limited resources. This paper implements an OpenStack cloud computing framework which can be used for diverse applications. It can be tailored according to the university needs such as a self service platform to achieve virtualization, to implement community clouds as collaboration between educational organizations or even as a test bed for students to develop applications. The paper also propounds on some use cases that are achievable with the cloud computing deployment.**

Keywords—Cloud Computing; Cloud Services; Education; IaaS;University ;Virtual Instances

I. INTRODUCTION

Any developing country, like India, which aims to scale to new heights of economic growth, has to endow the youth of the nation with the skill set that will help realize the aspirations of the developing country. A major role in this endeavor is by the temples of education; the schools and the universities. To achieve the optimal standards of quality education and with increasing population, the institutions are compelled to make the existing resources more productive. Since cloud computing is capable of optimizing the current resource utilization, more and more institutes are turning to cloud solutions [1].

Cloud computing is a standard which combines several existing IT technologies into one service [4]. It is a progression of virtualization, Grid Computing, Utility Computing, Web services and Internet. By bringing together the finest industry standards, the computing framework drives the dexterity of virtualization, scalability of grid computing and modesty of web 2.0 [1][2].

Adopting Cloud Computing model offers a shift from computing as a product that is owned, to computing as a service that is delivered to consumers over the network from large-scale data centres or clouds [2]. These services are tailored according to the needs of the end user and therefore, the cloud platform is a "user-guided" scheme for it moulds the resources to the users' preferences [3].

The traditional IT infrastructure does not have the convenience which a virtualized, rapidly scalable and demand based self-servicing environment provides to an organization. This coupled with the end users' desire for uninterrupted service irrespective of day, place and time is encouraging the enterprises to adopt the cloud model for their businesses. Moving to cloud also means that their CAPEX notably comes down while improving the quality of the service provided [5].

Information assimilation, processing and making it available when required is the most critical task for any enterprise. The same holds true for the academe, be it a school or a university. The primary advantages that cloud computing presents to an organization, an enterprise in general and a university in particular are [6]:

- Focusing on core Competencies: Allows the organization to concentrate on information management, policy decisions to boost learning without concern for the data center management.
- Sustainability: Compared to traditional data center services, better economies of scale and the capability to manage the computing assets smoothly leads to low energy and resource utilization.
- Flexibility: Adopting cloud computing allows access to resources, information and services independent of the device & location. It tailors the IT resources to match the organizational goals.
- Scalability: As the load or the user base of the cloud varies the resource capacity is scaled accordingly.

The current hardware and software architecture, staff and management competence along with legal and policy compulsions in higher education influences the degree of profit, capability to grasp it and the proportion of expense to gain attained by shifting to cloud. The cloud computing deployment model also determines the extent of benefit for a university. The public cloud infrastructure will have deep positive impact on small colleges and universities by allowing access to avant-grade applications & services. On the other hand, a university may choose to deploy its own private cloud or DIY (Do It Yourself) cloud for its own consumption in

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addition to offering services to the students and other universities [6].

Cloud computing has a pivotal position to usher in monumental change in teaching & learning methodologies to benefit the vast Indian education quarter. It can rally the varied resources spread across regions in prudent manner [1]. Therefore, the basic ground work for the cloud deployment has to be initiated at the universities so as to assess the most impactful cloud deployment suitable to the needs of the student, teaching and research community is achieved. Hence, the best way to do this is by leveraging the benefits of open source platforms to deploy a private cloud.

This paper shows a basic cloud IaaS setup to create virtual instances using OpenStack for a higher education university. Such an IaaS deployment can be utilised for various university activities and initiatives. The rest of the paper is organised into 4 sections. Section 2 presents the literature review focusing on the cloud computing initiatives with respect to educational institutions. Section 3 presents our proposed solution. Section 4 shows the current implementation and section 5 discusses the future scope and concludes the paper.

II. LITERATURE REVIEW

Cloud computing solutions in education sector will allow the focus to remain on teaching and research activities without having to worry about how limited resources can be put to optimal utilization to service the ever increasing base of the users.

A. Cloud Computing Framework/ Architecture in Education

Academic information management has been stressed in Thailand as part of developmental efforts by their government. The Thai qualifications framework for higher education, a component of their National Education Act, is a quality assurance tool to improve the graduate education standards [15]. With the task of fulfilling the objectives laid out in this framework, architecture of Information management system, with cloud computing being its fundamental pillar, has been developed. Quality assurance is assured through seven factors: implementation, store, collection, communication, control and follow up, knowledge sharing and information accessing among administrator, instructor and student [15]. Madhav et al have proposed a virtual computing labs framework based on cloud computing for higher educational institutions [16]. Their framework comprises of "computer services", "data services" and "network services" through which resource sharing and scalability can be achieved among other benefits for the educational institute. Shardrom et al have proposed an E-Learning educational cloud architecture comprising of three layers: "Resource Layer", "Middleware Layer" and "Application Layer". It covers both the front end and the back end. The physical cloud components form the back end while the front end is user servicing end [17]. The resource layer forms the backend of this architecture. The application layer is the front end component providing services to the user. Middleware layer facilitates the availability for user oriented services that virtualization, data storage etc.

B. Virtual Desktop solutions in Educational Institutions

The Cisco virtual desktop solutions expressly dispenses swift stationing of desktops and grants remarkable regulation and surveillance of the desktops much as decreasing the Total Cost of Ownership(TCO) [7]. The stakeholders have a protected connection to centrally handled desktops irrespective of the device or network. A similar solution was developed in-house at the University of Huddersfield that deployed an OpenStack IaaS and used the resources to provision virtual systems which can be instantiated by students [8]. This created an environment of virtual laboratory. On similar lines, the framework for virtual computing labs implemented by using Microsoft Azure exemplifies how the unification of the services creates a robust virtual cloud lab [16].

In the Indian context, the Kendriya Vidalaya Schools have made an initiative to develop an Educational School Cloud which includes provisioning Virtual PCs for students and teachers among other services [9]. Such virtual desktop solutions offer a number of advantages to educational institutions by reducing the capital expenditure as well as operational costs while offering increased security and data protection [7].

C. Cloud Computing Impact on Distance Education

Another dimension of the education sector is the distance education mode. Present-day Distance Education objective is to fulfill 4A, namely Anyone, Anytime, Anyplace & Anything i.e. any person at any time, any place can be learning any content [1]. Cloud computing solutions for distance education can help realize the goal of 4A. For the Spanish National University for Distance Education (UNED, *Universidad Nacional de Educación a Distancia*), the cloud platform is the correct decision to proficiently manage its technological framework [3]. UNED is working on exploiting cloud technology to handle its technological infrastructure, so that fault-tolerance, scalability, and low power utilization are realized. Development of algorithms to supervise the machines of the University; perform forecasts of their load based on Exponential Smoothing and dynamically provision the resources and maintain load balancing [3]. The same university also hosts the development of Laboratories as a Service (LaaS) [10], which allow users of remote laboratories create resourceful experiments fitted to their needs [10].

D. Tackeling expoenential data storage growth in Cloud

A case study discusses how the Ben-Gurion University in Israel actualized a "Storage On-demand" model that permits researchers, labs, and whole departments to access managed disk space on an as-needed basis. The increase in the user base over time is managed by ensuring the backup of information. The efficient utilization of the on-demand-storage services increased to 83% from 65% by reducing the storage management requirements [1].

E. SaaS applications for Education

Microsoft Intune for Education [11] is a set of cloud-based management tools for schools to deploy and manage Intune for Education does not have a lot of overhead in setting up the

environment on windows 10 and effortlessly enables the control of shared devices.

Google for education [12] is a suite of productivity applications that facilitate better knowledge flow using the various Google applications like Docs, Sheets etc., which also encourage student interactions and collaborations.

III. Proposed Solution: On-Premise Open Source Cloud

OpenStack since its inception has come a long way, and has established a niche for itself to emerge as an open standard for IaaS cloud platform and has generated a lot of buzz in the research community. OpenStack is a collective venture between the National Aeronautics and Space Administration (NASA) and Rackspace. The open source cloud packages collectively implement the IaaS platform [8]. Currently these packages consist of Keystone (user management module), Nova (compute module), Glance (image management module), Neutron (network module), Swift (object storage) and Cinder (block storage). Apart from the core services the elective services, like Horizon (web-based user interface portal), further enhance the cloud proficiency [8] [13]. OpenStack offers enhanced flexibility to manage the user base. For example, certain proportion of the computational resources can be accessed by the users assigned to projects [8].

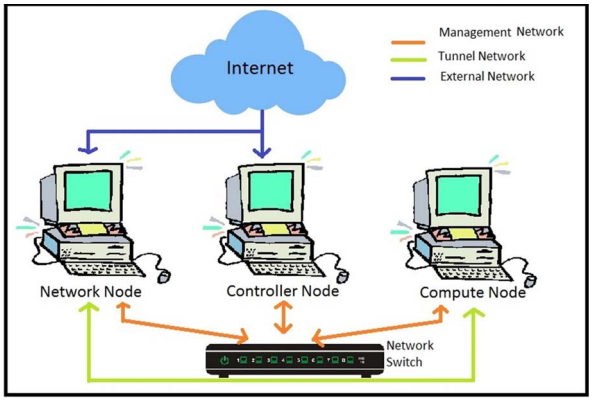

Fig 1: Topology of the cloud network.

We have deployed the OpenStack Juno release as its one of the stable releases that has been around for quite some time now. For our deployment the under lying hardware specifications are [14]:

- RAM: 4GB
- Processor: Intel Core i7-3770 CPU @ 3.40GHz *8
- OS: Ubuntu 15.10 LTS, 64 bit
- Disk: 500 GB

The above specifications were common for all the 3 nodes i.e.,

- The controller node [14]: The management services are run here for Openstack operation
- Compute Node [14]: Runs the virtual machine instances in OpenStack.
- Network Node [14]: The networking services, virtual network provisioning is accomplished here. It also connects the virtual machines to the external networks.

The network layout is shown in Figure 1.

Once the deployment is successful in creating new virtual instances, such virtual instances can be utilised for various kinds of applications to achieve the organisational goals.

A. Learning Scenarios

In an open source DIY cloud environment like this, some of the learning scenarios that the user can experience are discussed.

- User Accounts

The users will have their accounts on the cloud environment such that the services relevant to them can be delivered. Each of these accounts will be customised based on the basic parameters of course, year of study, subject choices for the students. For the teachers the basic parameters of customisation are the courses, classes they teach, department, their designation etc. Depending on the type of the account, relevant information like course content, circulars, schedules etc, can be delivered to the user. For the teachers, additional services that can enable them to modify the schedule according to the real time situation can also be extended.

- Tailored Course Content

Specific to the user account the users will have the relevant subjects delivered to them which can be accessed anytime, anywhere.

- Cloud Assignments

The teachers can send assignments to students. These assignments would be sent based on some parameters so that its relevance is preserved. Similarly the students can submit the assignments back to the teachers for assessment.

- Virtual Labs

In technical institutions, labs are an important asset to the students to gain practical knowledge, lab work integrated with the cloud would make the work accessible to the students, teachers alike.

- Cloud Attendance

There are electronic attendance systems in place for teachers and other university officials. Integrating such systems with the cloud would make information flow smooth and transparent.

- Resource Virtualization

Resources like network, storage and computing resources are virtualized in cloud environment. Such virtualised resources can be provisioned to students, teachers and administration in the university. These resources can be then tailored for wide ranging purposes.

- University Collaborations

Computing and other resources from different universities can be shared based on need without much effort. This would enable quick provisioning of resources facilitated by the hybrid cloud.

IV. Implementation & Results

The cloud deployment can begin after all the nodes are properly configured according to the topology (see Figure 1 and Figure 2) and the network interfaces are well defined.

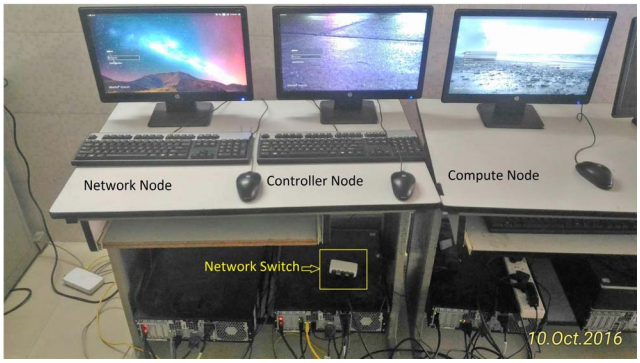

Fig 2: Physical hardware used for Cloud Implementation.

A. Controller Node

The supporting services (MySql database, Message broker: RabbitMQ & Network Time Protocol (NTP)) on the node are installed first. The NTP properly synchronizes the services among nodes. Here the controller node references more accurate servers for time synchronization while the other nodes refer the controller node [14]. The OpenStack services' information is stored in the SQL database. We have used MySql database. For operation and status information coordination a message broker is used. Generally the controller node runs the message broker service RabbitMQ, Qpid and ZeroMQ are examples of message brokers supported by OpenStack [14]. We have used RabbitMQ. Once the supporting services are installed, the basic OpenStack services are installed (keystone, glance, nova, neutron and horizon) on the controller. The services running on the controller node are shown in the Figure 3.

B. Network Node

After configuring the controller node we proceeded to setting up the network node. Switching, routing, NAT and DHCP services along with the network plug-in and agents (see Figure 4) provisioning tenant networks operate from this node. For successful deployment these service agents should be running at all times.

If during configuring of these services there are any errors discovered then the log files have to be checked for finding the root cause.

Also, it was observed that these services may fluctuate from active to non-active state. This is seen mainly because of the time delay between the service getting active and the time of reporting the state to the controller node by the management network.

The external connectivity for the tenant virtual machine instances is provided by this node [14].

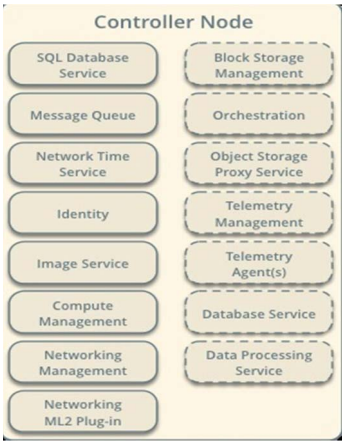

Fig 3: The services on the controller node [14].

```
root@controller:/home/controller# neutron agent-list
+--------------------------------------+--------------------+---------+
| id                                   | agent_type         | host    |
+--------------------------------------+--------------------+---------+
| 1567db01-b245-44cf-9c7a-065574650654 | L3 agent           | network |
| 3d2fad38-6ac5-4887-97de-f9c64d4f065e | DHCP agent         | network |
| aa5ba260-0563-49fc-a070-f747a81cbc16 | Open vSwitch agent | network |
| b3240a91-2b69-4189-9a1f-ce37c485a00b | Metadata agent     | network |
| db8af266-2210-4a16-b175-eee23b3a6ae7 | Open vSwitch agent | compute |
+--------------------------------------+--------------------+---------+
      +-------+----------------+---------------------------+
      | alive | admin_state_up | binary                    |
      +-------+----------------+---------------------------+
      | :-)   | True           | neutron-l3-agent          |
      | :-)   | True           | neutron-dhcp-agent        |
      | :-)   | True           | neutron-openvswitch-agent |
      | :-)   | True           | neutron-metadata-agent    |
      | :-)   | True           | neutron-openvswitch-agent |
      +-------+----------------+---------------------------+
```

Fig 4: Neutron and compute agents running successfully. Operation verified on controller.

C. Compute Node

The hypervisor chunk of compute that handles virtual instances is run on the compute node. KVM (Kernel-based Virtual Machine) is the default hypervisor on the compute. But it is important to determine if the compute node supports hardware acceleration of virtual machines. It will support hardware acceleration if a value of one or more is returned for the command ***egrep -c '(vmx|svm)' /proc/cpuinfo*** [14]. If zero is returned for this command then hardware acceleration is not supported hence QEMU (Quick Emulator) is used instead of KVM [14].

The compute node also runs the Networking plug-in (see Figure 4) and an agent that connect tenant networks to instances and provide firewalling (security groups) services. There can be more than one compute node.

D. Launching an instance

An instance is a virtual machine which is provisioned on the OpenStack compute node [14]. By adding the CirrOS image to our environment a minimal instance was launched.

The successful launch of the VM indicates the deployment of the OpenStack Cloud Computing Platform. This computing platform can now be utilised for the university. The deployment can be provisioned as a platform to providing virtual networking that will optimise the hardware utilisation. The platform can become test bed to deploy PaaS services by the students. This will prove to be a great learning for the students. The setup could also be used to deliver storage virtualisation replacing the traditional servers or better utilize the legacy systems using the deployed cloud.

Some of the use cases have been tabulated in Table 1.

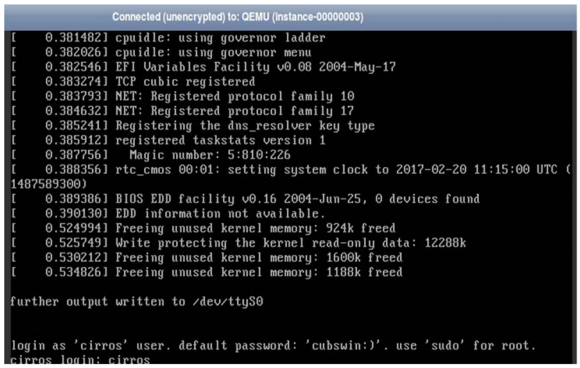

Fig 5: Successfully launch instance via the Horizon Dashboard from the controller node.

TABLE I. USE CASE OF CLOUD COMPUTING PLATFORM

Use Case	Use Case Description
Database of alumni students in university.[1]	A database to record the details of the alumni of college/university to prevent misuse/ malpractices to curb false claims.[1]
Integrated University Administration	A cloud solution to integrate all the departments of the university under one cloud storage platform that gives authorised access to the patrons to access the information on the go.
Cloud to support student learning.	Various SaaS applications tailored according to the curriculum of the university along with dispensing relevant student related information via the Application. The app can also be designed to provide assignment submissions and feedback system. Implementing the virtual lab solutions in the university.

V. CONCLUSION & FUTURE SCOPE

Cloud technologies enable the pro-efficient use of technological framework. To overcome the shortage of the resources faced by the higher learning institutions, cloud computing emerges as the frontrunner. Cloud allows the focus to remain on core competencies. Apart from this, the adoption of cloud allows significant cost reduction, better resource utilization, rapid scalability among other benefits.

This paper demonstrated a successful OpenStack cloud computing deployment.

Our future work involves utilising this computing platform to implement a host of services which can help students, teachers and administrators. For students, solutions such as virtual labs, automated attendance systems, automated assignment submission systems and the computing platform itself can put the students in a position to gain a lot of knowledge.

For the administrators and teachers, the storage and network virtualization can be of great help as it will ensure optimal utilization of the existing resources while maximizing the user base.

The deployment can be used to also host free course ware that can be easily provisioned to other universities or for provisioning students in distance education mode, etc.

So the bottom line is there are host of possibilities that can be leveraged from the cloud deployment.

REFERENCES

[1] D. G. Chandra and M. D. Borah, "Cost benefit analysis of cloud computing in education", in *International Conference on Computing, Communication and Applications*, Dindigul, Tamilnadu, 2012, pp. 1-6. doi: 10.1109/ICCCA.2012.6179142

[2] A. Tashkandi and I. Al-Jabri, "Cloud Computing Adoption by Higher Education Institutions in Saudi Arabia: Analysis Based on TOE", in: *International Conference on Cloud Computing (ICCC)*, Riyadh, 2015, pp. 1-8.

[3] A. C. Caminero, S. Ros, R. Hernández, A. Robles-Gómez and R. Pastor, "Cloud-based e-learning infrastructures with load forecasting mechanism based on Exponential Smoothing: A use case", in: *Frontiers in Education Conference (FIE)*, Rapid City, SD, 2011, pp. S3C-1-S3C-6.

[4] N. Alkhater, G. Wills and R. Walters, "Factors Influencing an Organisation's Intention to Adopt Cloud Computing in Saudi Arabia", in: *IEEE 6th International Conference on Cloud Computing Technology and Science*, Singapore, 2014, pp. 1040-1044.

[5] How is Cloud Computing Different from Traditional IT Infrastructure, Web page at https://www.leadingedgetech.co.uk/it-services/it-consultancy-services/cloud-computing/how-is-cloud-computing-different-from-traditional-it-infrastructure/ . Date of last access: 03rd March 2017.

[6] Cisco (2010),"Cloud Computing in Higher Education: A Guide to Evaluation and Adoption", [Online] Available: http://www.cisco.com/web/offer/email/43468/5/Cloud_ Computing_in_ Higher_Education.pdf

[7] Cisco, "Simplify desktop management, Enhance Security and Lower costs with Cisco Virtual Desktop Solutions", [Online] Available: https://www.cisco.com/c/dam/en/us/solutions/collateral/data-center-virtualization/dc-partner-vmware/cisco_education.pdf.

[8] S. Bonner, C. Pulley, I. Kureshi, V. Holmes, J. Brennan and Y. James, "Using OpenStack to improve student experience in an H.E. environment" in *Science and Information Conference*, London, 2013, pp. 888-893.

[9] A. Paventhan, H. Krishna, V. Gayathri and N. Pahuja, "Towards educational school cloud for India: A case study with Kendriya Vidyalayas", in *IEEE Region 10 Humanitarian Technology Conference (R10 HTC)*, Chennai, 2014, pp. 46-51.

[10] A. C. Caminero *et al*., "Deconstructing remote laboratories to create Laboratories as a Service (LaaS)", in: *2014 IEEE Global Engineering Education Conference (EDUCON)*, Istanbul, 2014, pp. 623-629.

[11] Yusuf Mehdi, (January 24th 2017), Announcing Intune for Education & new Windows 10 PCs for school starting at $189 [Web Page]. Retreived from URL: https://blogs.windows.com/windowsexperience/2017/01/24/announcing-intune-education-new-windows-10-pcs-school-starting-189/

[12] "Google for Education" [Online] Available: https://edu.google.com/ Last accessed on 3rd March 2017

[13] "OpenStack",[Online] Available: https://www.openstack.org/software/ Last accessed on 3ed March 2017.

[14] OpenStack Installation Guide for Ubuntu, juno(December 2015)

[15] T. Rodmunkong, P. Wannapiroon and P. Nilsook, "The architecture of Information Management System through cloud computing according to Thai Qualifications Framework for Higher Education," *2015 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*, Zhuhai, 2015, pp. 181-188. doi: 10.1109/TALE.2015.7386041

[16] N. Madhav and M. K. Joseph, "Cloud-based Virtual Computing Labs for HEIs," *2016 IEEE International Conference on Emerging Technologies and Innovative Business Practices for the Transformation of Societies (EmergiTech)*, Balaclava, 2016, pp. 373-377. doi: 10.1109/EmergiTech.2016.7737369

[17] S. Johnson *et al*., "A Framework of e-Learning Education Clouds to Efficiency and Personalization," *2016 3rd International Conference on Information Science and Control Engineering (ICISCE)*, Beijing, 2016, pp. 26-30. doi: 10.1109/ICISCE.2016.17