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## California State University, San Bernardino managing cloud computing resources with CloudStack using KVM hypervisor

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CALIFORNIA STATE UNIVERSITY, SAN BERNARDINO  
MANAGING CLOUD COMPUTING RESOURCES  
WITH CLOUDSTACK USING KVM HYPERVISOR

---

A Project  
Presented to the  
Faculty of  
California State University,  
San Bernardino

---

In Partial Fulfillment  
of the Requirements for the Degree  
Master of Science  
in  
Computer Science

---

by  
Ian Buckner Jacobs  
December 2013

CALIFORNIA STATE UNIVERSITY, SAN BERNARDINO  
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Ian Buckner Jacobs

December 2013

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20 Nov 2013  
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## ABSTRACT

Virtualization technology has been around for many years. The ability to virtualize a desktop operating system has really developed over the last decade. The ability to virtualize an OS has increased the ability to have meaningful academic teaching that can be used in a classroom or on-line. In this day, we can virtualize more than just an operating system or a server. Now we can virtualize software, storage, platforms (exchange, etc.), and the infrastructure that can have all of the above. A number of large businesses provide these at a cost. This paper proposes using CloudStack Virtual Management software and KVM (included with most Linux distributions) to host virtual machines to create a low-cost or free environment that can be used in an academic environment to teach certain concepts. Currently on campus we have two different cloud or virtual technologies that are designed to host larger numbers of servers and desktops. These include VMware and Citrix. Both of these have their advantages and disadvantages, the biggest disadvantage would be the cost. My project would like to introduce a third cloud environment, a very low end version for an initial test. Using CloudStack as the cloud management tool and KVM as the virtual host. Both of these are open source with no cost. In this project, I compared a basic installation of VMware and CloudStack. Comparing the installation and management abilities, specifically, complexity of installation, management of the two systems, and user experience. The value of this work opens the possibility of a low cost Cloud experience.

## ACKNOWLEDGEMENTS

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# CHAPTER ONE

## SOFTWARE REQUIREMENTS SPECIFICATION

### 1.1 Introduction to the Project

This project is for a master degree in the School of Computer Science and Engineering in California State University, San Bernardino. The title of the project is “CSUSB Cloud Computing: Managing Resources with CloudStack using KVM Hypervisor.” The objective of this project is to install, implement, and then review a low cost open source virtual resource management system, that includes CloudStack and KVM, and compare it to VMware and Citrix. CloudStack is designed for a higher end management of resources. This project will implement a basic installation of this software that will emulate VMware VSphere, commercial grade software.

### 1.2 Purpose

The purpose of this document is to present a detailed description of the Enterprise Cloud Computing implementation of CloudStack using KVM. It will explain the purpose and features of the system, the interfaces of the system, what the system will do, and the constraints or limitations implementing CloudStack with the hardware available for this study.

### 1.3 Scope of Project

This software system will be an implementation of a low cost cloud computing installation using CloudStack and KVM virtual hosting or an equivalent. The installation will try to use equipment that is currently not being used. The final product will be a low end version of a cloud environment that could be used by CSE students. The goal of this project is to create a cloud based virtual environment that the students can use individually. This will allow each student to have individualized hands-on learning and experience. This final result is limited by available hardware.

Prototype 1 will provide access to multiple VM's for students via a provisioning interface.

More specifically, this system is designed to allow an end user (student) to manage and use a virtual environment that may contain multiple VM instances. For this project we will focus on creating an environment similar to VSphere, a product by VMware. CloudStack will be used as the management portal and KVM as the hypervisor, both of these have minimal or no cost. Available hardware is a limitation of this implementation.

### 1.4 Significance of the Project

The making of the "Cloud" is a convergence of technology. This convergence of technology is why this paper has value in our environment.

Convergence technology or unified computing are terms used in the

computing world. Some vendors call it one thing or another. But the idea is to centralize and combine resources and thus creating the Cloud for online access.

“The result is a pooling of physical servers, network resources and storage resources that can be assigned on-demand. This approach lets IT operators rapidly re-purpose servers or entire environments without having to physically reconfigure I/O components by hand, and without the requirement of hypervisors. It massively reduces the quantity and expense of the physical I/O and networking components as well as the time required to configure them. A converged infrastructure approach offers an elegant, simple-to-manage approach to data centre infrastructure administration.” [1, p. 2]

By providing the same service, most technology centers are used to having servers, storage, and network infrastructure. We can reduce the overall foot print of a data center. This foot print would include: providing the same level of service with less overall infrastructure.

By reducing the overall footprint of the hardware, small data centers can exist that provide equal service. This reduced office space will also reduce the overall expenses to house the data center. This would include cost per foot for the data center, the cost for air-conditioning the space, and the electrical requirement will also be reduced. There will a cost increase to purchase higher end servers that can provide for this service.

This has also opened up the market where large data centers can provide services for other companies.



## 1.5 Others Who are also Looking at this Technology

### 1.5.1 University of Utah

A graduate student in Information Systems, David Eccles School of Business, University of Utah has a similar senior project. “We are doing a CloudStack implementation for the David Eccles School of Business as our senior project for the Masters of Science in Information Systems program at the University of Utah.” [2, p. 1]

They have allocated more resources to their University of Utah project. The project I am doing here at CSUSB has limited resources, so the implementation is very basic.

### 1.5.2 Fresno State

The Keck Computational Science Center (KCSC) at The College of Science and Mathematics at California State University, Fresno has implemented a CloudStack infrastructure that supports a number of departments at the university. [3]

## 1.6 Definitions

Virtual Machine (VM): “A VM is a software implementation of a computing environment in which an operating system (OS) or program can be installed and run.” [4, p. 1] “A VM is a simulation of a machine (abstract or real) that is usually different from the target machine (where it is being simulated on).” [5, p. 1] “VM

may be based on specifications of a hypothetical computer or emulate the computer architecture and functions of a real world computer.” [5, p. 1]

Host (Network): “A network host is a computer connected to a computer network. A network host may offer information resources, services, and applications to users or other nodes on the network. A network host is a network node that is assigned a network layer host address.” [6, p. 1]

Kernel-based Virtual Machine (KVM): KVM is a virtualization infrastructure for the Linux kernel. KVM requires a processor with hardware virtualization extension. [7, p. 1]

CloudStack: “Apache CloudStack is an open source software designed to deploy and manage large networks of virtual machines, as a highly available, highly scalable Infrastructure as a Service (IaaS) cloud computing platform.” [8, p. 1]

Software as a service (SaaS): “SaaS, pronounced sæes or sas, sometimes referred to as ‘on-demand software’... is a software delivery model in which software and associated data are centrally hosted on the cloud. SaaS is typically accessed by users using a thin client via a Web browser.” [9, p. 1]

Platform as a service (PaaS): “is a category of cloud computing services that provide a computing platform and a solution stack as a service. Along with software as a service (SaaS) and infrastructure as a service (IaaS), it is a service model of cloud computing. In this model, the consumer creates the software using tools and/or libraries from the provider. The consumer also controls

software deployment and configuration settings. The provider provides the networks, servers, storage and other services." [10, p. 1]

Infrastructure as a service (IaaS): "offer computers - physical or (more often) virtual machines - and other resources... Pools of hypervisors within the cloud operational support-system can support large numbers of virtual machines and the ability to scale services up and down according to customers' varying requirements. IaaS clouds often offer additional resources such as images in a virtual-machine image-library, raw (block) and file-based storage, firewalls, load balancers, IP addresses, virtual local area networks (VLANs), and software bundles." [11, p. 7]

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." [12, p. 2]

Network as a service (NaaS): "a category of cloud services where the capability provided to the cloud service user is to use network/transport connectivity services and/or inter-cloud network connectivity services. NaaS involves the optimization of resource allocations by considering network and computing resources as a unified whole." [11, p. 9]

Virtual private network (VPN): "extends a private network and the resources contained in the network across public networks like the Internet. It

enables a host computer to send and receive data across shared or public networks as if it were a private network with all the functionality, security and management policies of the private network. This is done by establishing a virtual point-to-point connection through the use of dedicated connections, encryption, or a combination of the two." [13, p. 1]

### 1.7 Deployment Design

The initial design included three servers, each with three network cards to isolate different network traffic (See Figure 1). Initially there was a CloudStack server, a server to host the SQL server, and then a server that was the Host system for all the virtual machines. This is the area that could be expanded with additional virtual host servers.

### Deployment Diagram

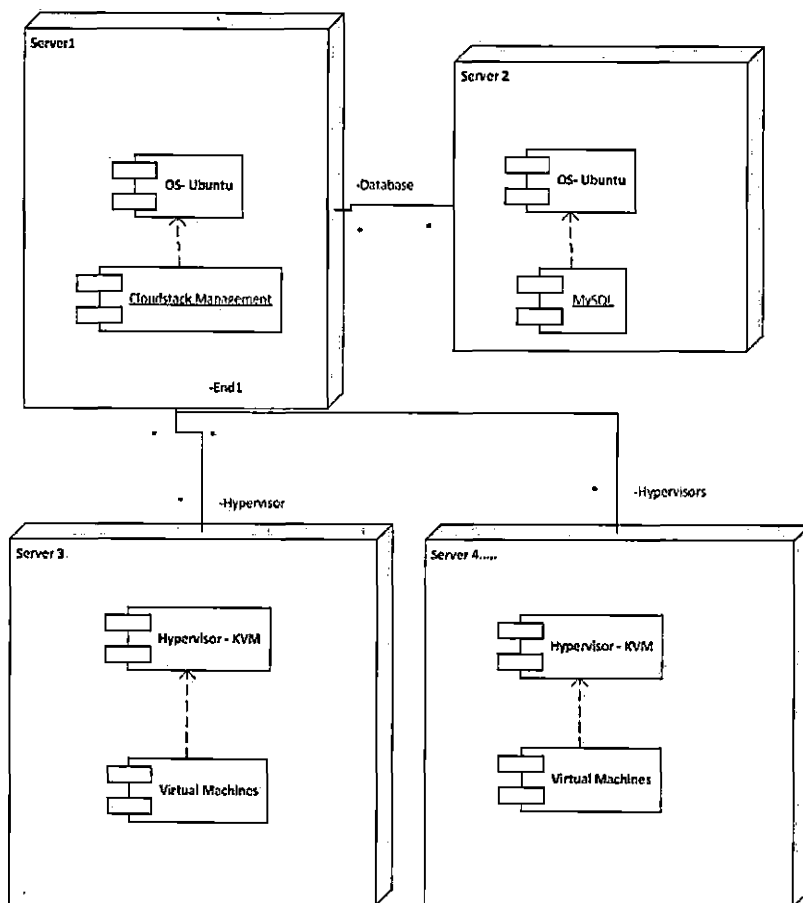


Figure 1. Initial Deployment Diagram Proposal

## 1.8 Users in the System Environment

The Cloud Computing System has four types of users: The System Admin, Account Admin, Account User, and Public who may access the Cloud through the Internet (See Figure 2). The System Admin can also access the entire system directly when needed.

### 1.8.1 Functional Requirements Specification

This section outlines how each type of person would access the cloud environment to manage or use the VM's and configure the virtual network.

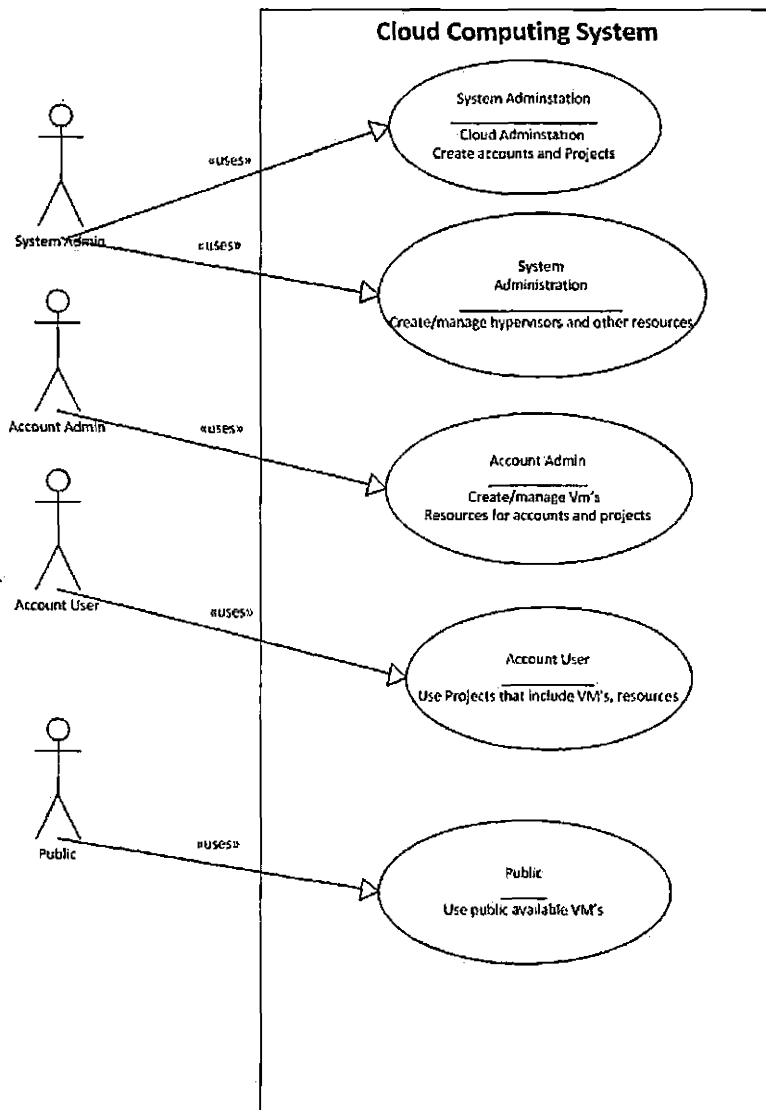


Figure 2. Use Case Diagram – Users in the CloudStack System

1.8.1.1 System Admin. The System Admin accesses CloudStack through a Web interface or a command line of each hypervisor. The System Admin has multiple roles. Create and manage the cloud infrastructure. This includes the

initial setup of the management interface. The management product, CloudStack, can communicate with the hypervisors that are located at some physical site. The system Admin will need to create the infrastructure that the hypervisors can connect to. From the web interface the admin uses the console to create different types of access or services. Types of services could include: IaaS, SaaS, PaaS, and NaaS.

1.8.1.2 Account Admin. The Account Admin can be a user or can manage multiple VM's that are assigned to a project. VM's can be created using this account.

1.8.1.3 Account User. The account user is assigned to a project to get access to VM's that are created by an Account Admin or System Admin.

1.8.1.4 Public User. Although there is not an actual public user defined in CloudStack we still need public user. The public user can access Internet services or applications (SaaS) that are hosted on the internet facing VM's. This could include: Webservers, FTP servers, corporate databases.

## 1.8.2 User Characteristics

All users are expected to be Internet literate and be able to access the available interfaces. The System Admin and Account Admin are expected to have knowledge of Servers, network, and security. The Account User should have some basic knowledge of servers.



## 1.9 Requirements Specification

Different users may require internet access to their VM's. If the VM has a normal internet routable IP, then a user can remote in to the VM directly. If the VM has a non-routable IP, then the user will need access to the VM via the console proxy.

## 1.10 External Interface Requirements

The whole idea of Cloud Computing is to allow access to Network services over a network, typically the Internet. Users should be able to access the Cloud for administering the VM's. End users should be able to access any publicly directed services.

### 1.10.1 User Login Interface

The user interface is access via a Website. This is the same address as the admin login. A user will input a domain in the login interface. (See Figure 3) Depending on what type of user you are, as described in the Use Case of user roles, will depend on what type access you will get. (See Figure 2)

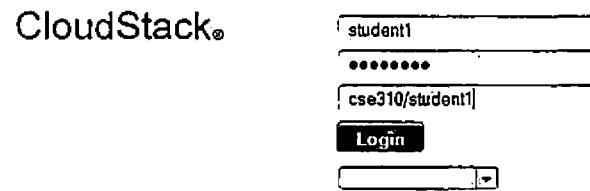


Figure 3. CloudStack User Login

### 1.10.2 User Interface

The user interface includes a basic dashboard related to the user. This shows the number VM's and how many are up and running. (See Figure 4)

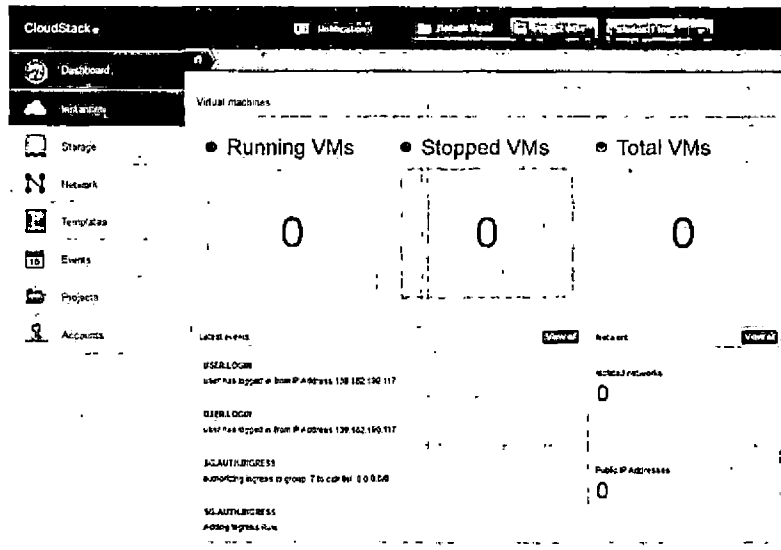


Figure 4. User Dashboard

The user can access their instances from the link on the left. Instances associated with a project are only available from within the project.

### 1.10.3 Functional Requirements

CloudStack is an open source cloud computing software for creating, managing, and deploying infrastructure cloud services. It uses existing hypervisors such as Oracle VM, KVM, vSphere/ESXi, and XenServer for virtualization. For this project, KVM will be used as a low cost hypervisor. KVM is included with most Linux distributions.

#### 1.10.4 Security

CloudStack has its own security model. Users are created with a password. Projects are created that have VM's assigned to them. Resources are available based on a security setting. Access to the resource can be based on a user, project, or public that can access the network services, such as, Webservers.

## CHAPTER TWO

### CLOUD COMPUTING USING CLOUDSTACK

The installation of our cloud environment will mainly focus on CloudStack. VMware will be discussed, but the installation information is located in the Appendix.

#### 2.1 Installation and Use of CloudStack

Ubuntu 12.04 was the base operating system installed on the server. (See Appendix A) CloudStack was installed on top of Ubuntu. MySQL is installed as part of the CloudStack installation. (See Appendix B) Since we are using one server for this project, KVM is also installed on this server. (See Appendix C)

##### 2.1.1 Login into CloudStack

Management and user connections to CloudStack are via a web interface. The login screen allows access to the admin console or a user console. The admin logs in with a user name and password. The Admin account does not fill in the Domain are. (See Figure 5)

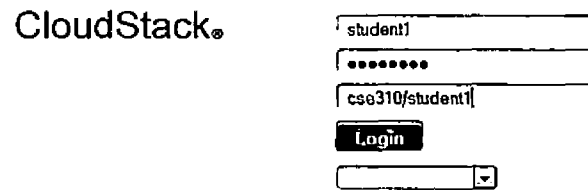


Figure 5. CloudStack Admin Login

### 2.1.2 Initial Screen – Admin

The initial screen for the Admin account shows the dashboard of overall resources. The layout has different areas on the left, alerts at the top, and the overall condition of the allocated resources. If you will notice the Zone1 shared Network IP's is maxed out. (See Figure 6) Memory and CPU usage are also referenced.

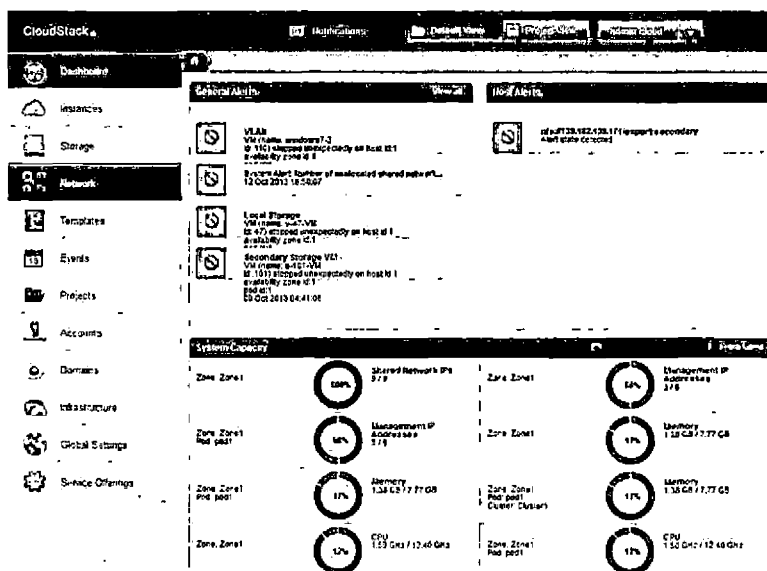


Figure 6. Admin Dashboard Screen

### 2.1.3 CloudStack Infrastructure

The infrastructure view shows how many Zones are defined, along with the Pods, clusters, and hosts. A Zone can hold many Pods. A Pod can have a number of clusters that include the same type of host (virtual server). (See Figure 7) Within a Zone, a Secondary Storage is established that all hosts can access. A Primary storage is established for each Cluster.

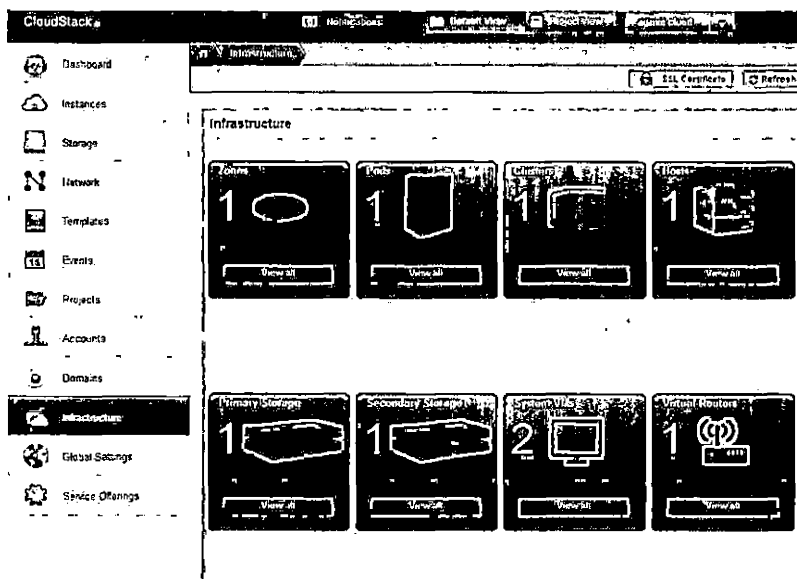


Figure 7. Infrastructure Admin View

Expanding the Zone list you can see the hierarchy better (See Figure 8).  
You can see how the Secondary Storage is aligned with the Zone and the  
Primary Storage is aligned with the Cluster.



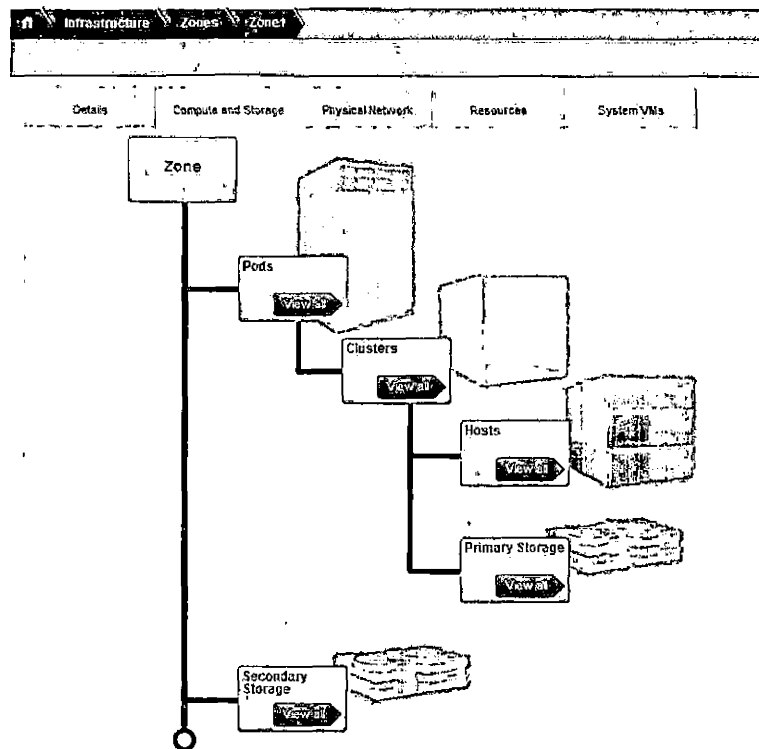


Figure 8. Hierarchy View of Infrastructure

#### 2.1.4 Creating a Domain

From the main management Web interface, select the Domains link on the left column. Select the current domain (initially this is the root). Select the center tab in the middle of the screen to add a new Domain under the current domain. (See Figure 9) This will allow some isolation of how resources are used by users or projects.

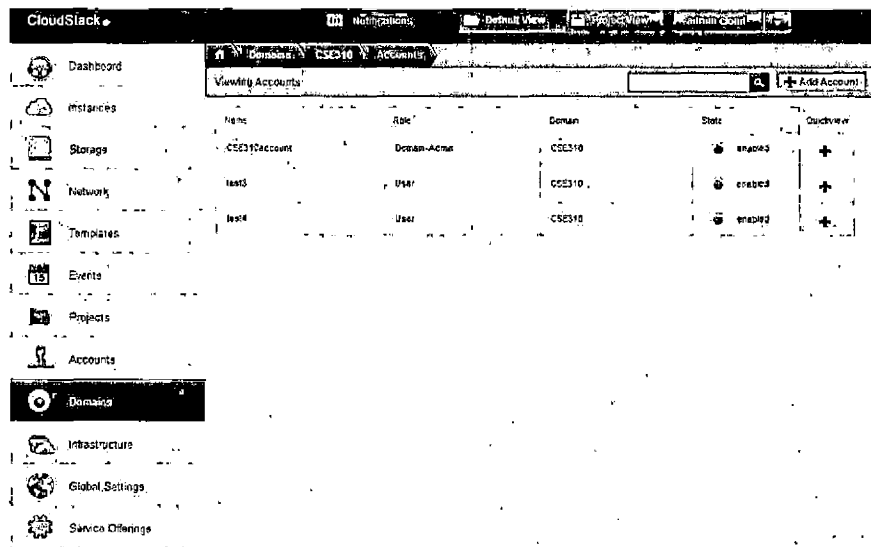


Figure 9. Domain Listings

### 2.1.5 Creating Users

There are two ways to add a user. The first one for creating an account is done by selecting the Accounts button on the left column. This will bring up a list of current accounts. (See Figure 10) Each account is associated with a role (Admin, Domain-Admin and User) and a Domain. There is also a state indicator which indicates whether an account is enabled or not.

The screenshot shows the CloudStack Accounts page. The left sidebar contains navigation links for Dashboard, Instances, Storage, Network, Templates, Events, Projects, Accounts (selected), Domains, Infrastructure, Global Settings, and Service Offerings. The main content area is titled 'Viewing Accounts' and contains a table with the following data:

Name	Role	Domain	State	Quickview
admin	Admin	ROOT	enabled	+
CSE310account	Domain-Admin	CSE310	enabled	+
test3	User	CSE310	enabled	+
test4	User	CSE310	enabled	+
student1	User	student	enabled	+

Figure 10. Admin Account List

Within this window on the upper right area is a link to Add Account. A popup will ask for username, password, first and last name, the domain to associate this account to and the type of user. (See Figure 11)

**Add Account**

Add Account

\* Username:

\* Password:

\* Confirm password:

\* Email:

\* First Name:

\* Last Name:

\* Domain: ROOT

Account:

\* Type: User

Timezone:

Network Domain:

Cancel OK

Figure 11. Account Info Required

2.1.5.1 Types of Users/Roles. Previously in this document the User roles were defined; Admin, Domain-Admin, and User. (See Figure 2)

### 2.1.6 Creating Projects

Projects are created within a domain and then users are assigned to be in a project. (See Figure 12) A user can be part of multiple projects. But the resources in each project are independent of each other. A project can be defined under a Domain by the Admin or within the domain by the Domain-Admin.

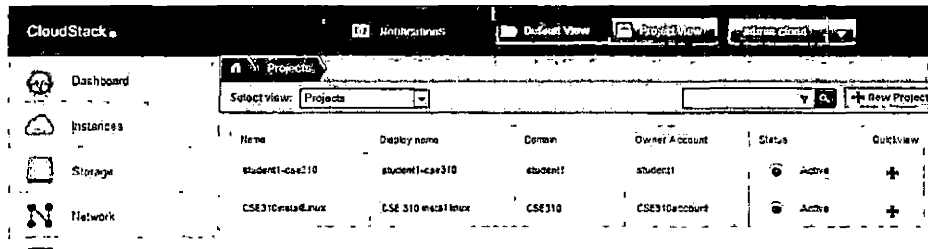


Figure 12. Projects Admin View

### 2.1.7 Importing ISO's

Importing ISO's into CloudStack is not straight forward. The ISO must be imported from a Web site located outside of CloudStack. So you need the exact address and filename to import with. You can define the ISO also; Bootable, Public (available to everyone). (See Figure 12 and Figure 13) Templates will be discussed later.

Register ISO

\* Name:

\* Description:

\* URL:

Zone: All Zones

Bootable:

\* OS Type: Asianux 3(32-bit)

Extractable:

Public:

Featured:

Cancel OK

Figure 13. ISO Import

ISO listings can be seen by the Admin and users if the ISO is marked as public. (See Figure 14)

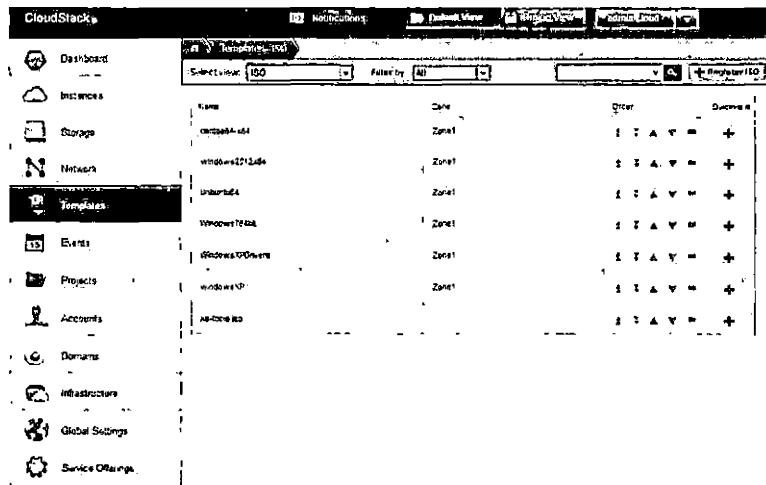


Figure 14. ISO Listings

### 2.1.8 Event Info

On the left side in the Admin view you also have an Event view. Information can be found here related to: logins, VM's being created and destroyed, firewall rules being modified, ISO imported or removed, Templates being created, etc. (See Figure 15)

Description	User	Domain	Account	Date	Delete
User has logged in from IP Address 129.162.190.117	root	root	admin	18 Oct 2013 07:15:48	+
User has logged in from IP Address 159.182.194.117	root	student1	student1	15 Oct 2013 07:13:51	+
User has logged in	root	root	admin	14 Oct 2013 22:17:12	+
Adding ingress rule	root	student1	student1	15 Oct 2013 02:12:43	+
authorizing ingress to group 7 to cidr list 0.0.0.0/0	root	student1	student1	15 Oct 2013 02:12:43	+
Successfully completed Adding ingress rule	root	student1	student1	15 Oct 2013 02:12:43	+
authorizing ingress to group 7 to cidr list 0.0.0.0/0	root	student1	student1	15 Oct 2013 02:12:10	+
Successfully completed Adding ingress rule	root	student1	student1	15 Oct 2013 02:12:10	+
Adding ingress rule	root	student1	student1	15 Oct 2013 02:12:10	+
Successfully completed Adding ingress rule	root	student1	student1	15 Oct 2013 02:09:49	+
Adding ingress rule	root	student1	student1	15 Oct 2013 02:09:49	+
authorizing ingress to group 7 to cidr list 0.0.0.0/0	root	student1	student1	15 Oct 2013 02:09:49	+
User has logged in from IP Address 129.162.190.117	root	root	admin	15 Oct 2013 02:09:48	+

Figure 15. Events in Admin View

### 2.1.9 Creating VM's from ISO's and Templates

To create a VM, you can choose between an ISO (See Figure 17) and a Template. (See Figure 16)



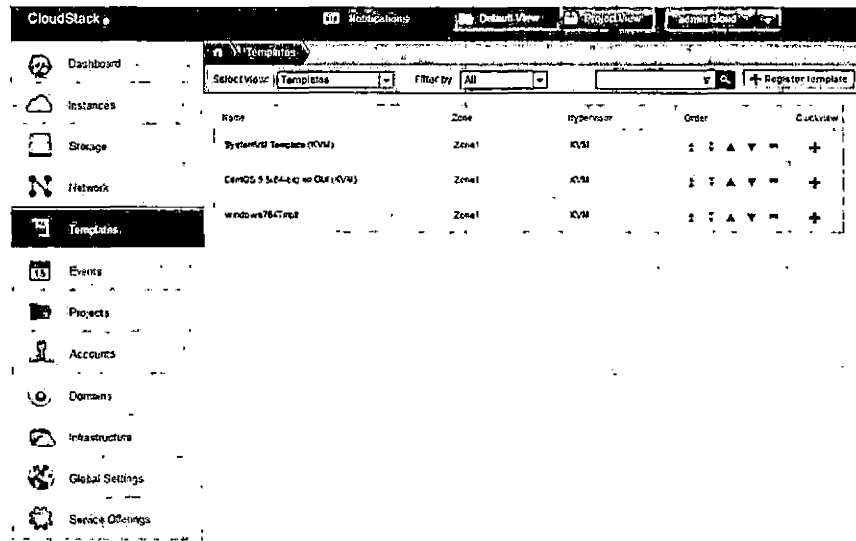


Figure 16. Template Listing

A template is an image that has been created previously with an ISO and now you can create an instance very quickly from an image that has been preconfigured as needed.

Name	Zone	Order	Quickview
centos64-bit	Zone1	1	+
windows701b.64	Zone1	2	+
debian64	Zone1	3	+
windows764bit	Zone1	4	+
WindowsXP64bit	Zone1	5	+
windowsXP	Zone1	6	+
ubuntu.64	Zone1	7	+

Figure 17. ISO Listing

### 2.1.10 Using Security Groups

Security Groups can be used to control some network traffic (See Figure 18). The Security group can have the ingress and egress rules modified to control network traffic.

Name	Description	Domain	Account	Quickview
CSE310SEC	CSE310SEC	ROOT	admin	+
default	Default Security Group	student1	student1	+

Figure 18. Security Group

## 2.2 Cloud Computing Using VSphere and VMware ESXi 5.1

### 2.2.1 Installation and use of VMware ESXi 5.1

This document has focused on the installation of CloudStack. For the installation instructions for VMware ESXi 5.1, please refer to appendix. (See Appendix E)

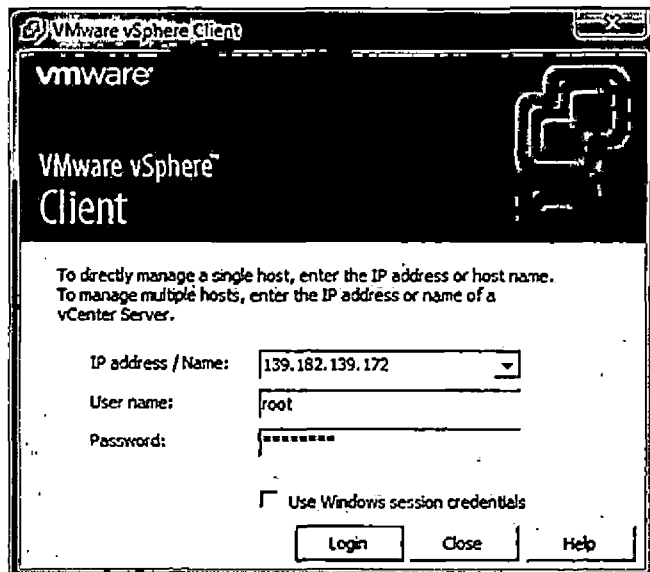


Figure 19. VMware vSphere Client

### 2.2.2 VMware ESXi and VSphere

ESXi is the hypervisor and it is where the virtual machines are running. A VSphere Client is installed on the local computer, such as, Windows 7. (See

Figure 19) Through the VSphere client the bare metal installation of ESXi can be managed. Using the Client, we input the VSphere IP address, login name, and password. Within the client we can create accounts, create instances, manage network interfaces, and other management tasks. (See Figure 20)

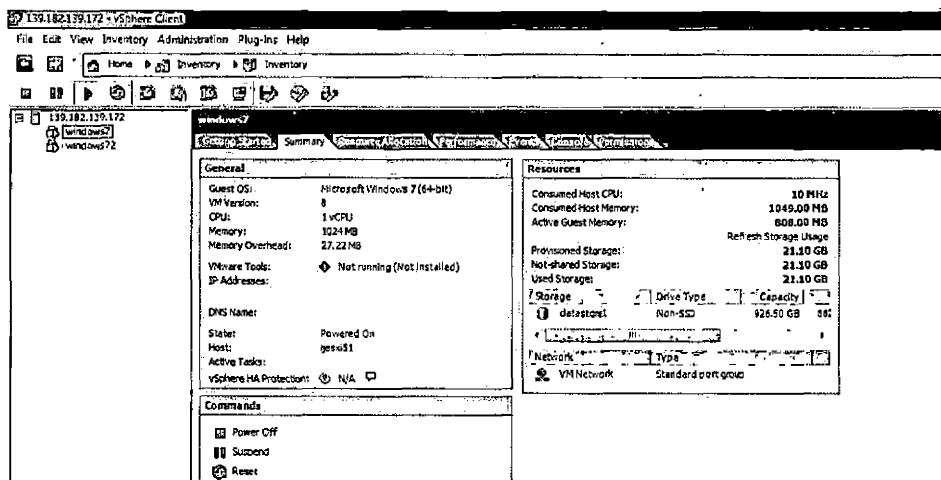


Figure 20. VMware VSphere Interface

## CHAPTER THREE

### INSTALLATION AND DIFFICULTIES

#### 3.1 Issues and Difficulties Installing CloudStack vs. VMware

Installing CloudStack and KVM is not straight forward. A good working knowledge of a Linux helps in the installation process. In the recommended installation of CloudStack, a minimum of three servers with three network cards in each connected to a layer 2 switch with three VLANs defined on the switch were needed. For this research we had a couple of servers to work with but all the servers were on the same VLAN and switch.

A number of weeks were used to try to implement this system on multiple servers over the single network and a single switch. This limitation and my basic knowledge of Linux, the system did not function.

So a single Network card design was implemented. This limited the ability to create the virtual network that was intended. So the servers were combined into one server. After Ubuntu was installed, CloudStack was installed, and then KVM was installed on the same system. This has limited my design that I wanted to implement.

#### 3.2 Final Design

The final design included one server. With the limitation of only having one network card available for this project, the design had to be changed and one

server was used. (See Figure 21) So the CloudStack management server with MySQL was installed on Ubuntu. KVM was then installed on the same server. This limited the overall ability of the system for this project.

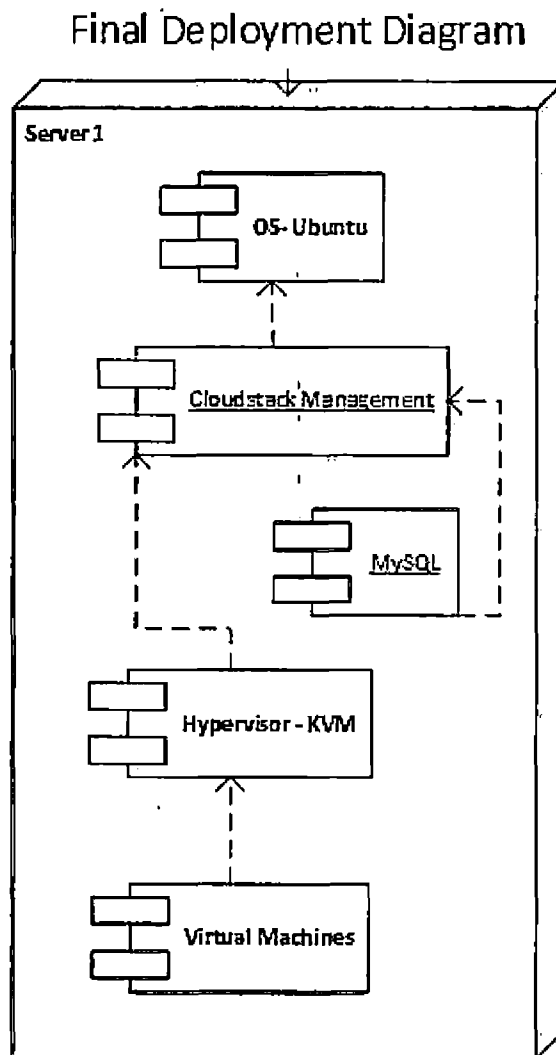


Figure 21 Final Deployment Diagram

Over the summer, I installed these systems a number of times. First, Ubuntu 12.04 was installed with SSH and Virtual support (See Appendix A). Each system, CloudStack and KVM require a number of command line functions typed. This left room for errors in typing and bad installations. I found a script on the Internet that inspired me to modify it for my needs for installing CloudStack (see Appendix B) and KVM (See Appendix C). This decreased the install times and reduced the number of installation typos. Since I ended up using one server, the KVM script had to be modified to allow for a previous installation of CloudStack.

### 3.3 Templates and ISO's for Installation on Both Platforms

Implementing or copying in an ISO for use by VM's was more difficult in CloudStack than in VMware. A separate web server (see APPENDIX D) was used to import ISO's from another location. This had many issues initially because the Secondary Storage System VM that manages ISO's and templates and is automatically created by CloudStack, had difficulties seeing the outside world.(See Figure 22) This was one of the issues using one network card on multiple system created.

Name	Type	Zone	Status	Quickview
s-101-VM	Secondary Storage VM	Zone 1	Running	+
v-112-VM	Console Proxy VM	Zone 1	Running	+

Figure 22. Secondary Storage VM (SSVM)

In VMware VSphere you find the location you want the ISO to be located and upload the ISO to that location from the local computer using the client.

To create a template in CloudStack, you need to first create a working instance from an ISO. Install all applications that you want including all the updates. After you have finished configuring the instance, shutdown the instance. Then select the image. (See Figure 23 )

Name	Image name	Copy name	Zone name	State	Quickview
WindowsTest1	i2-114-VM	Windows7Guest	Zone1	Stopped	+

Figure 23. Instance for Making a Template



On the right hand side select the View Volumes button. (See Figure 24)

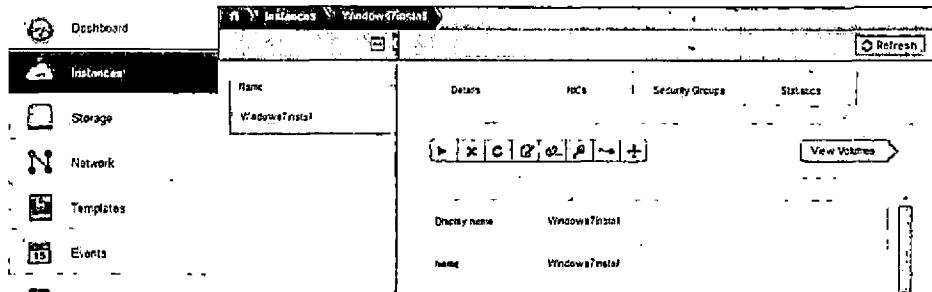


Figure 24. Instance Menu Including Volumes

From within the instance volume you can select the create template button (forth button) (See Figure 25)

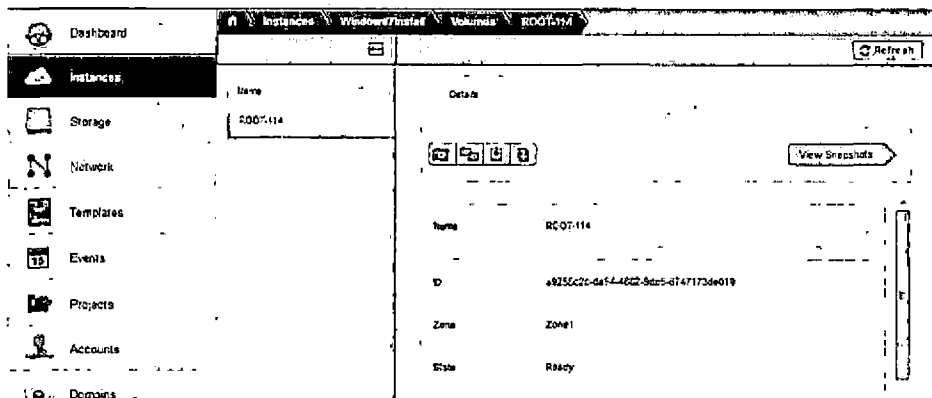
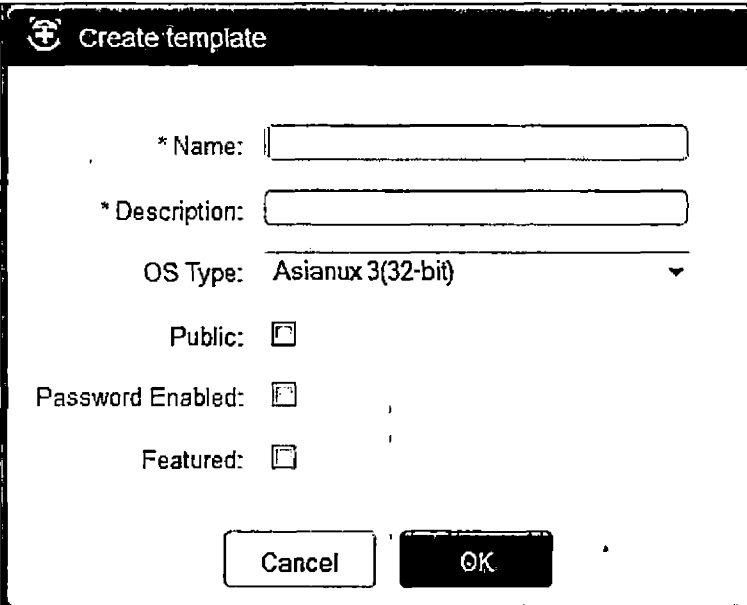


Figure 25. Volume Control of Instance Including Template Creation

Creating the template requires a name, description, what type Operating System it is. You can also select who has access to this template. (See Figure 26)



The image shows a 'Create template' dialog box. It has a title bar with a plus icon and the text 'Create template'. The dialog contains the following fields and controls:

- \* Name: [Text input field]
- \* Description: [Text input field]
- OS Type: Asianux 3(32-bit) [Dropdown menu]
- Public:
- Password Enabled:
- Featured:
- Buttons: Cancel, OK

Figure 26. New Template Name and OS Type.

### 3.4 My Experience with CloudStack

The interface of CloudStack is simple for some items, creating a user, creating a project, overall usage of resources, etc. CloudStack has areas that are complicated or could be a little easier to work with. The setup for the IP

addresses for a Zone/Pod/Cluster are not so simple in design. The importing of ISO's could be simpler. VMware ESXi seems to be better designed to configure. The cost of VMware or other managed hypervisors may still be the deciding factor on whether to implement a CloudStack environment or not.

## CHAPTER FOUR

### METHODS AND TESTING

#### 4.0 Methods

Methods for testing the hypothesis of creating a low cost, using available hardware, cloud computing environment is described in this chapter. I installed CloudStack on one server. This design has limitations. I simulated the creation of a class and student account for CSE 455 Software Engineering and CSE 360 Script Programming in the School of Computer Science and Engineering. I will compare the installation times, complexity, and reliability of CloudStack (4.1)/KVM with a per cost cloud environment such as VSphere managing VMware ESXi 5.1. The final outcome will be a beta test environment that can lead into a larger implementation.

#### 4.1 Limitations of Comparison

The installation was limited to the hardware that was available which is one server that included a quad processor, 8 gigabytes of RAM, and one network card. CloudStack is designed to be an enterprise level manager. In this project, I implemented the cloud in a much smaller environment. CloudStack prefers to have three or more network cards connected to a layer 2 switch with three different VLANs for traffic management. The installation of the CloudStack environment was initially implemented with multiple servers for distribution of

resources needed to manage the system. A lot of time was used to get this to work. After a number of failed attempts, a single server with one network card was used. Because of the limited Network cards and available switches, only one server was used.

## 4.2 Installation

VMware ESXi with VSphere installation is initially straight forward. The installation CD installs in about 20 minutes. From the server you configure a login/password and then the IP information. After that, all other configurations are done using a software client from another system.

For CloudStack, there were a number of steps. The initial installation was a base installation of Ubuntu 1204LTS. The base installation included SSH server and the virtual server. This base installation also included all the network information. Then a number of steps are taken to prep the computer to begin the installation of CloudStack. (See APPENDIX A). The installation time was decreased by automating using a script. (See script included in CD) The script concept was from another programmer, referenced in the comments of the script. I modified it for my installation of CloudStack. Installation includes: updates to Ubuntu, installation of MySQL, a script to modify the database for use by CloudStack, system changes, Firewall rules, setting up and testing of the Primary and Secondary Storage areas using NFS, the downloading of an initial template

that can be used by CloudStack, and of course the installation of the CloudStack manager.

The next step is to install the KVM software that will be the virtual host (See Appendix C). If we are installing this on a separate physical server, we would start out similarly as CloudStack. I found I needed to do a script for this to decrease the install time and reduce typos. But since we installed this on the same server as CloudStack was installed, the script was modified to skip those commands that are not needed.

#### 4.2.1 Installation Times

The time to install each of the virtual technologies is an indication of the complexity of the system to manage. (See Table 1)

Table 1. Installation Times for VMware and CloudStack/KVM

Product	ESXi 5.1	Ubuntu12.4LTS Base	CloudStack 4.1	KVM
Time (mm:ss)	18:20	17:40	8:30	6:25
Time without scripts	n/a	n/a	45:30	22:30

The installation of CloudStack manually without the script was very susceptible to typos and possible missed steps. Whereas, ESXi was designed specifically to perform as expected. In less than twenty minutes, ESXi was ready

to go. But the script definitely improved the installation times for CloudStack and KVM. (See Table 1) But it was still twice as long for the installation. This is done only once, so the longer time and complexity is dealt with only once.

#### 4.3 Complexity and Configuration of Client

VMware uses a client to access and manage the server. This same client is used by users to access their assigned VM's. This can be a pro and a con. A client has to be installed on whatever platform you have. There are different Clients for a number of operating systems for VMware. The CloudStack console is via the Web. The user logs into CloudStack and then through the Web interface a console can be started up to access assigned VM's. Multiple VM's can be accessed, but it is not as responsive as the VMware client. The VMware client gives an optimized performance for the user. CloudStack UI can manage the administration essentials and configurations via the Web interface.

#### 4.4 Complexity of Managing Clouds

To implement each design in a production environment would require high level hardware to be purchased. The current hardware will work for a single sample design. In CloudStack you can add a user into a previously created Domain. In fact, the Domain-Admin can add existing users to their domain. Within the domain, multiple projects can be created that users can share resources as defined by the Domain-Admin. A user can then create their own

projects to manage personal projects. In VMware VSphere, a user can be created and then associated with a VM or multiple VM's.

## 4.5 Creating a Cloud Environment for CSE Course

### 4.5.1 CSE455

This is a software engineering course that is required for a BS in Computer Science, BS in Computer Engineering, and a BA in Computer Science programs. I added a Domain with the class name. (See Figure 27)

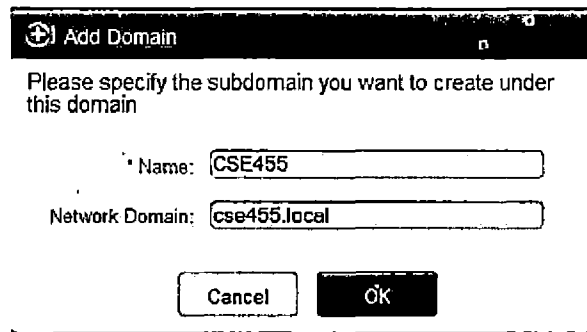


Figure 27. Adding a Domain

Then I added a user within this domain. Other information is requested. (See Figure 28)



The screenshot shows a dialog box titled "Add Account". It contains the following fields and options:

- \* Username:
- \* Password:
- \* Confirm password:
- \* Email:
- \* First Name:
- \* Last Name:
- \* Domain:  (dropdown menu)
- Account:
- \* Type:  (dropdown menu)
- Timezone:  (dropdown menu)
- Network Domain:

At the bottom of the dialog are two buttons: "Cancel" and "OK".

Figure 28. Adding User and Put in the Right Domain

Here is a list of the accounts in in the CSE455 domain. Other accounts have been created. (See Figure 29)

Domains CSE455 Accounts				
Viewing Accounts				
Name	Role	Domain	State	Quickview
cse455admin	Domain-Admin	CSE455	enabled	+
cse455student1	User	CSE455	enabled	+
cse455student2	User	CSE455	enabled	+
cse455student3	User	CSE455	enabled	+

Figure 29. Listing of Accounts in this Domain. Includes Domain Admin.

Create a project for the user to use. More than one user can share a project and resources. (See Figure 30)

**New Project**

### Create project

Project name:

Display Text:

Figure 30. Create a Project

Add user(s) to the project. A project can have multiple instances associated with it. (See Figure 31)

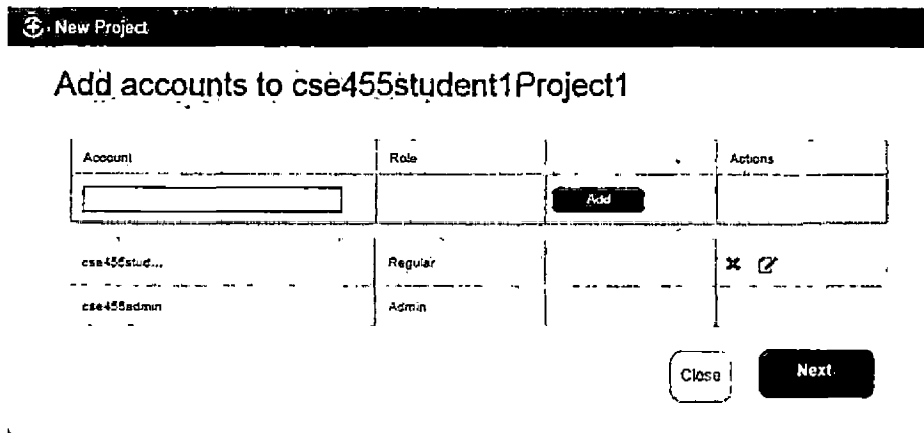


Figure 31. Add a User to the Project.

Create an instance for the domain using the CSE455 security group. The instance will have CPU, memory, and hard drive space associated with it. (See Figure 32)

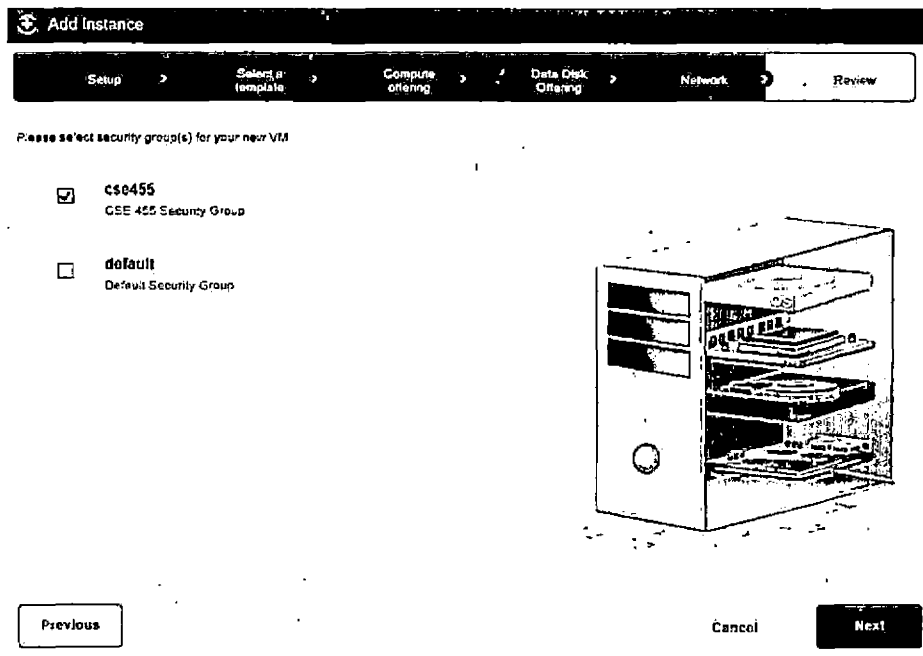


Figure 32. Creating an Instance

After a successful installation of the image or instance of Ubuntu, the console is opened up. (See Figure 33)

```
LinuxGitRepos - Windows Internet Explorer
http://139.182.139.171:8080/client_console?cmd=access&vm=c2b7ab9f-4ff2-4a19-a08c-432945641071

Ubuntu 12.04.1 LTS LinuxGitRepos tty1
LinuxGitRepos login: ljacobs
Password:
Welcome to Ubuntu 12.04.1 LTS (GNU/Linux 3.2.0-29-generic x86_64)

 * Documentation:  http://help.ubuntu.com/

System Information as of Wed Oct 23 20:37:56 PDT 2013

System load:  0.07          Processes:      68
Usage of /:   11.7% of 9.28GB Users logged in: 0
Memory usage: 7%          IP address for eth0: 139.182.139.217
Swap usage:   0%

Graph this data and manage this system at https://landscape.canonical.com/

136 packages can be updated.
67 updates are security updates.

The programs included with the Ubuntu system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Ubuntu comes with ABSOLUTELY NO WARRANTY, to the extent permitted by
applicable law.

ljacobs@LinuxGitRepos:~$ _
```

Figure 33. Console of Ubuntu Instance

Using the security group previously defined, port 22 is opened up for outside access for SSH. (See Figure 34)

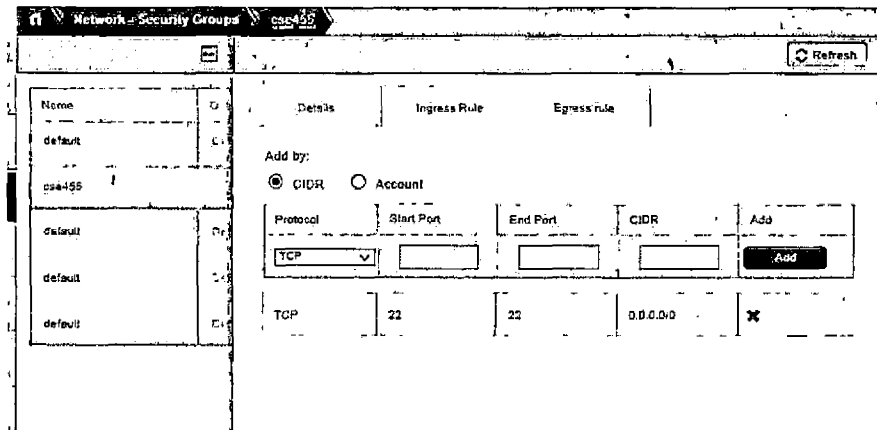
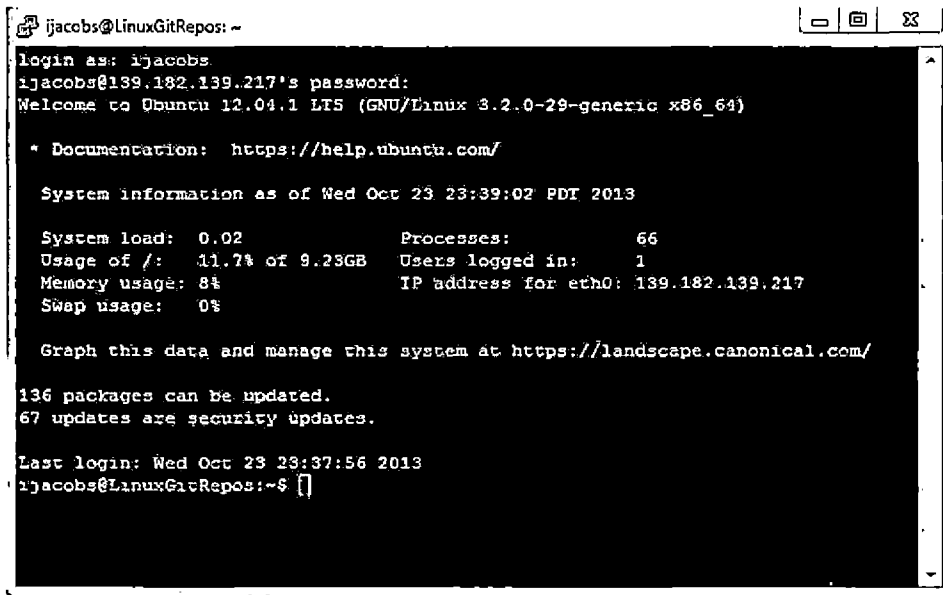


Figure 34. Security Group has Firewall Rule Modified for SSH Access.

Using SSH from outside of CloudStack, connected to instance. (See Figure 35)

A terminal window titled 'ijacobs@LinuxGitRepos: ~' showing the process of logging into a Linux server via SSH. The output includes the login prompt, password entry, a welcome message for Ubuntu 12.04.1 LTS, system information (system load, processes, memory usage, etc.), and a prompt for the user to press a key.

```
ijacobs@LinuxGitRepos: ~
login as: ijacobs
ijacobs@139.182.139.217's password:
Welcome to Ubuntu 12.04.1 LTS (GNU/Linux 3.2.0-29-generic x86_64)

 * Documentation:  https://help.ubuntu.com/

System information as of Wed Oct 23 23:39:02 PDT 2013

System load:  0.02          Processes:      66
Usage of /:   11.7% of 9.25GB Users logged in:  1
Memory usage: 8%           IP address for eth0: 139.182.139.217
Swap usage:  0%

Graph this data and manage this system at https://landscape.canonical.com/

136 packages can be updated.
67 updates are security updates.

Last login: Wed Oct 23 23:37:56 2013
ijacobs@LinuxGitRepos:~$
```

Figure 35. Testing Firewall Rule by Connecting to Instance via SSH.

So a successful server has been created that includes outside access to the server via SSH.

#### 4.5.2 CSE360

This is a systems course on Linux scripting language. This course requires more instances per student. As with the CSE455, still create a student or user in a Domain, specifically CSE360 Domain. (See Figure 36) The project area is also created the same way as in CSE455, but each student will have either their own project or a shared project for those instances that require students to collaborate.

The screenshot shows a web interface for managing accounts. At the top, there is a breadcrumb 'Accounts' and a search bar. Below the search bar is a table with the following data:

Name	Role	Domain	State	Quickview
cse360admin	Domain-Admin	CSE360	enabled	+
cse360Student2	User	CSE360	enabled	+
cse360Student1	User	CSE360	enabled	+

Figure 36. Domain with Student Accounts

As before, a Security policy can be created. This could be one per user or one applied to the whole class depending on the need. (See Figure 37)

The screenshot shows a web interface for managing templates. At the top, there is a breadcrumb 'Templates', a 'Select view' dropdown set to 'Templates', and a 'Filter by' dropdown set to 'Mine'. Below these are search and 'Register template' buttons. The main content is a table with the following data:

Name	Zone	Hypervisor	Order	Quickview
UbuntuTpl1	Zone1	KVM	↑ ↓ ▲ ▼ =	+

Figure 37. Creation of Templates for Student Use

The DomainAdmin can create one or more default image/instance. Then take that instance and create a template that can be used to quickly create new instances for each user. (See Figure 38) The same template can be used more



than once by the same user. A typical student in CSE360 can have up to ten VM's by the end of the quarter. A typical class can have 30 students.

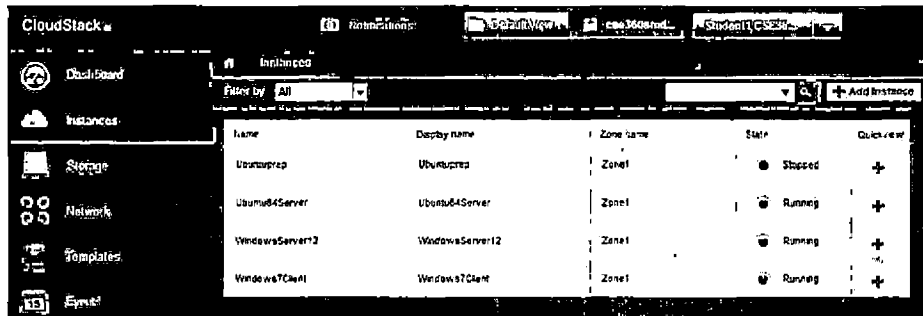


Figure 38. Multiple Instances for CSE360 Class

The hardware to support such a class of 300 VM's potentially running at the same time, is currently not available. Another limitation on this current implementation of CloudStack is the number of IP's assigned to this project.

#### 4.6 Summary

This chapter has described the complexity of managing and configuring the cloud infrastructure. We have also created a virtual server that can be made into a template for faster implementation or creation of new servers. More instances can be created for each user. An entire class could be implemented. This is limited by the hardware. While complexity is a level of discussion for this

project. Does the cost of purchasing VMware outweigh complexity of installing and managing CloudStack. This will depend on the available personnel who can manage the CloudStack system.

## CHAPTER FIVE

### CONCLUSION AND FUTURE DIRECTIONS

#### 5.1 Introduction

The project is a master degree project researching the feasible usage of the open source software, specifically CloudStack and KVM, to create a virtual cloud environment to manage virtual systems for student to use.

#### 5.2 Conclusion

The conclusions of the research are that CloudStack and KVM, both are open source, are a viable low cost software solution for creating a cloud environment. It is not a desktop infrastructure for pushing out to clients, such as Citrix and VMware can do. But it is a structure that can host a number of virtual desktops and servers for interaction within themselves or from the Internet. Thus allowing an entire class to have multiple instances per student. With the limitation being the hardware.

Two possible courses, CSE455 and CSE360, in virtual environments were created or discussed that could benefit from this technology. It would allow access to the VM's both in the classroom and from off campus.

CloudStack/KVM is more complex to configure and maintain the system. CloudStack requires more hands on and monitoring for a system admin than in a VMware infrastructure.

VMware ESXi with VSphere has cost to use it in a larger cloud environment, but it is a more stable product. CloudStack requires more hardware to support a similar configured ESXi server.

There is a great opportunity to expand the usage of CloudStack.

### 5.3 Summary

This project allowed me to better understand the cloud environments and what it will take to begin my own cloud services. I have all ways been interested in the administration of systems. This has allowed me to continue that research. Although complex, there are definitely benefits in this technology.

### 5.4 Future Work

I would hope that a student would take an interest in this area of cloud computing and services. The Apache CloudStack open source area still is looking for programmers to create write and test future revisions of the software. A larger implementation of this project could also be of value that could include other hypervisors, such as, Xen. There is great value in understanding the cloud environment. Forbes discusses the growth of cloud computing skills and future jobs related to cloud computing. [14] The number of jobs in this area continues to increase.

APPENDIX A  
INSTALLATION OF UBUNTU

Install Ubuntu 12.04 basic installation by downloading Ubuntu Server 12.04.1 LTS (Long Term Support) 64 Bit.

<http://www.ubuntu.com/download/server>

Save the ISO file to your local computer. Create a CD from the ISO file. Each desktop does this differently, Windows, Linux, and OSX.

Install Ubuntu server with the basic installation packages. As part of the installation include SSH server and the virtual support. You will need enough hard drive space to allow for the applications that will be run on it. You may have to install a separate hard drive(s) to host a shared location for files Primary and Secondary storage for CloudStack. In this environment we are using one server to handle on the server requirements. Therefore a large hard drive is needed. One Terabyte was used for this project. CloudStack requires a secondary storage area and a primary storage area.

APPENDIX B  
INSTALL CLOUDSTACK

Install CloudStack 4.x on basic installation of Ubuntu (see Appendix A).

After the basic installation of Ubuntu is complete, we need to prep for the CloudStack installation. A script is used as part of these commands. The script CloudstackautoinstallV#.sh (# is the version number) is available on CD with this project.

Login into the Ubuntu.

Make sure that BASH is installed on system.

```
$sudo apt-get install bash
```

After installation set bash as default for user.

```
$ sudo chsh -s /bin/bash <username>
```

```
$ sudo grep <username> /etc/passwd
```

You should see something like this.

```
$ <username>:x:1000:1000::/home/<username>:/bin/bash
```

Create a folder in the root of the system.

```
$ cd /
```

```
$sudo mkdir cloudstackinstall
```

```
$ cd /cloudstack
```

Then we need to get the automatic install script.

(See Appendix E) for small webserver that runs on windows.

CloudstackautoinstallV#.sh will need to be modified as needed and placed in Htdocs folder of web server.

```
$ sudo wget http://<ipaddress of web server>/CloudStackautoinstallV#.sh
```



After transfer of install script, sometimes the script may to be run through a text conversion program when using a window's based txt file to a Linux based text file.

Install the dos2unix command

```
$ sudo apt-get install dos2unix
```

Now we can run the script through the program.

```
$ sudo dos2unix CloudstackautoinstallV#.sh
```

The network information, server names should now be modified as needed in this script.

Also modify this file to change the password needed for this script. Delete it later.

Now we need to make this shell script executable.

```
$ sudo chmod +x CloudstackautoinstallV#.sh
```

Now we can begin the installation.

```
$sudo ./ CloudstackautoinstallV#.sh
```

The script will ask for some interaction.

APPENDIX C  
INSTALL KVM

Installation of KVM on Ubuntu. Install basic installation of Ubuntu. (See Appendix A) After the basic installation of Ubuntu is complete, we need to prep for the KVM installation. A script is used as part of these commands. The script KVMautoinstall#.sh (# is the version number) is available on CD with this project.

Login into the Ubuntu.

Make sure that BASH is installed on system.

```
$sudo apt-get install bash
```

After installation set bash as default for user.

```
$ sudo chsh -s /bin/bash <username>
```

```
$ sudo grep <username> /etc/passwd
```

You should see something like this.

```
$ <username>:x:1000:1000::/home/<username>:/bin/bash
```

Create a folder in the root of the system.

```
$ cd /
```

```
$sudo mkdir KVMinstall
```

```
$ cd / KVMinstall
```

Then we need to get the automatic install script. \*

See Appendix D for small webserver that runs on windows.

KVMautoinstall#.sh will need to be modified as needed and placed in Htdocs folder of web server.

```
$ sudo wget http://<ipaddress of web server>/ KVMautoinstallV#.sh
```

After transfer of install script, sometimes the script may to be run through a text conversion program when using a window's based txt file to a Linux based text file.

Install the dos2unix command

```
$ sudo apt-get install dos2unix
```

Now we can run the script through the program.

```
$ sudo dos2unix KVMautoinstall#.sh
```

The network information, server names should now be modified as needed in this script.

Also modify this file to change the password needed for this script. Delete it later.

Now we need to make this shell script executable.

```
$ sudo chmod +x KVMautoinstall#.sh
```

Now we can begin the installation.

```
$sudo ./ KVMautoinstall#.sh
```

The script will ask for some interaction.

APPENDIX D  
WEB SERVER

CloudStack requires a webserver to import ISO's from so Abyss Web Server was used in a windows environment. Abyss has a free version and a cost version. The free version was used for this project.

<http://www.aprelium.com/abyssws/download.php>

APPENDIX E  
VMWARE INSTALLATION

After creating you installation CD from the downloaded ISO from VMware, install it in your new ESXi server. The CD will boot into a Linux like kernel. The initial boot of the ESXi 5 CD will give a standard Linux type prompt. You have a couple of seconds to type in a command if needed. After those few seconds the installation will continue. The installation will turn more graphical with the familiar Yellow and black interface. The installation will ask to continue. The installation will ask you to enter a password. Then it will ask you for which keyboard to emulate. It will scan your hardware to check compatibility. When the install is finished you will have to reboot. After you reboot the ESXi server it will boot into its standard interface. This is where you can change the network settings. Once you have the standard interface running you can now change the network settings. To get to the settings you would hit the F2 key as indicated on the bottom left of the screen. The computer will ask you to login using the previously setup login name and password. Select the Configure Management Network to change the IP address. All further configuration will be done via the VMware client.



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