

A Cloud Computing Solution for Universities: Virtual Computing Lab

Case study of North Carolina State University's Virtual Computing Lab

Skill Level: Intermediate

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This article details the concept of cloud computing with the help of North Carolina State University's (NCSU) Virtual Computing Lab (VCL). We specifically focus on a cloud computing implementation methods through the VCL, how it helps within a research-oriented educational institution of higher learning, and finally, we discuss some of the important factors that demonstrate how NCSU VCL provides a scalable, sustainable, economically valuable and viable contribution to the campus layer IT cyber-infrastructure.

Introduction

Over the past few years, the concept of cloud computing and virtualization has gained much momentum and has become a more popular phrase in information technology. Many organizations have started implementing these new technologies to further reduce costs through improved machine utilization, reduced administration time and infrastructure costs. Cloud computing is the environment that enables customers to use applications on the Internet such as storing and protecting data while providing a service.

VCL is a cloud computing idea developed at the NCSU through a collaboration of its College of Engineering and IBM Virtual Computing Initiative to address a growing set of computational needs and user requirements for the university. This system can deliver user required solutions for variety of service environments anytime and anywhere on demand/reservation.

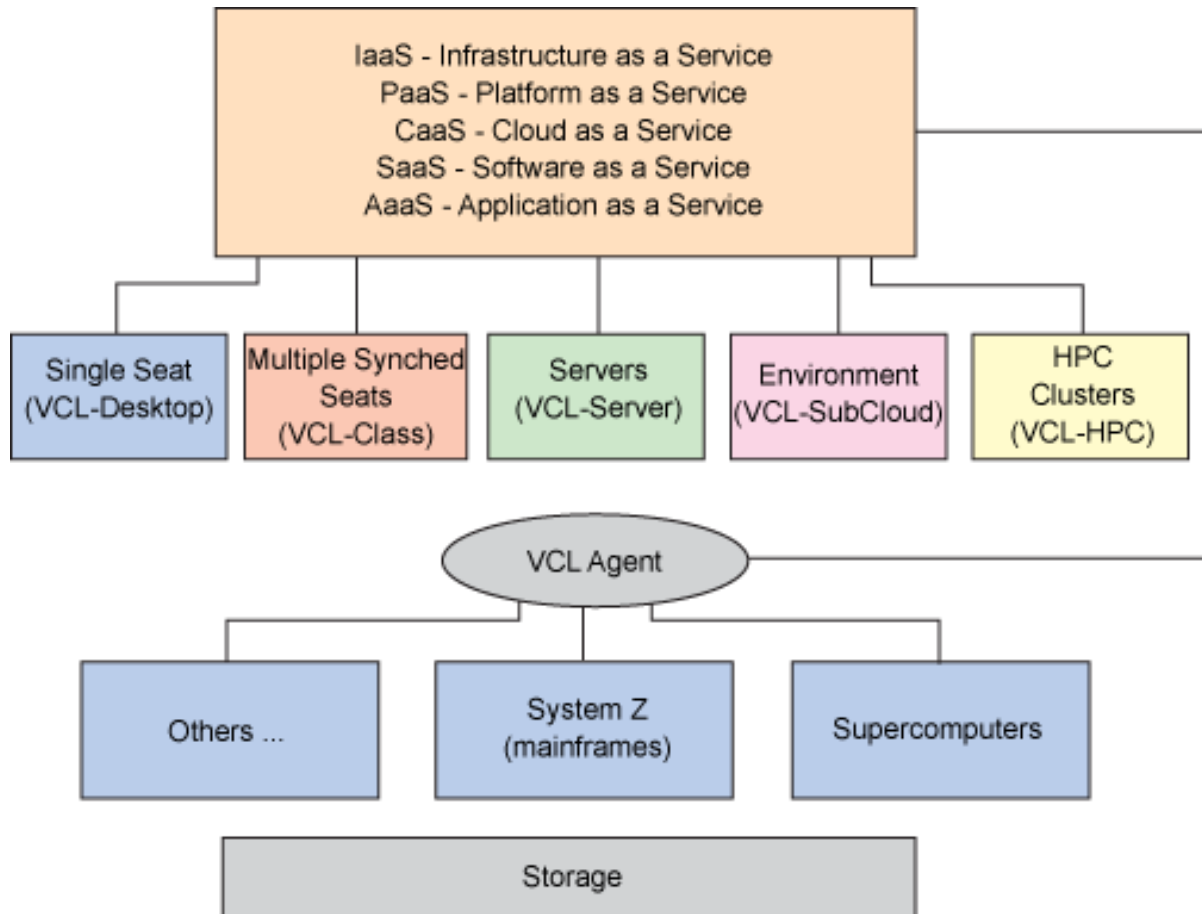
Architectural layers of cloud computing

A cloud computing platform dynamically provisions, configures, reconfigures, the servers as needed. Servers in the cloud can be physical machines or virtual machines. Advanced clouds typically include other computing resources such as storage area networks (SANs), network equipment, firewall and other security devices. In general, cloud service providers tend to offer services that can be grouped mostly into three categories:

1. Infrastructure as a service
2. Platform as a service
3. Software as a service

These categories grouped together and explained with the help of VCL in Figure 1. Read more details about cloud concepts in Resource section.

Figure 1. VCL Cloud Services



1. Infrastructure as a Service (IaaS)

IaaS is the delivery of computer infrastructure as a service. Infrastructure as a service offers computing capabilities and basic storage as standardized services over the network. Servers, storage systems, switches, routers, and other systems are reserved and made available to handle workloads. IaaS clouds make it very affordable way to provision resources such as servers, connections, storage, and related tools necessary to build an application environment from scratch on-demand.

The benefits of IaaS include rapid provisioning, ability to scale and pay only for what you use. For a startup or small business, one of the most difficult things is to keep capital expenditures under control. By moving your infrastructure to the cloud, you have the provision to scale as if you owned your own hardware and data center (which is not realistic with a traditional hosting provider) but you keep the upfront costs to a minimum.

VCL delivers different infrastructure at one place. It provides a platform (internally no physical infrastructure) virtualization environment in the Universities. Using this, student need not to set up any specific physical infrastructure for their project assignment. VCL provides following services for infrastructure.

- Compute
 - Physical Machines
 - Virtual Machines
 - OS-level virtualization
- Network
- Storage

VCL manager provides appropriate virtualization (aggregation, dis-aggregation) of the available hardware resources before mapping the requested image onto that hardware. VCL services focus on controlling the resource at the platform level.

2. Platform as a Service (PaaS)

Platform as a service is a virtualized platform that comprises one or more servers (virtualized over the set of physical servers), operating systems, and specific applications (such as Apache and MySQL for Web-based applications). In some cases, you can provide a VM image that contains all the necessary user-specific applications. Platform as a service comprise a layer of software and provides it as a service that can be used to build higher-level services. There are at least two perspectives on PaaS depending on the perspective of the producer or consumer of the services:

- The person *producing (Here VCL) PaaS* might produce a platform by integrating an OS, middleware, application software, and even a development environment that is then provided to a customer as a service.
- The person *using (users in Universities) PaaS* would see an encapsulated service that is presented to them through an interface. The customer interacts only with the platform through the interface, and the platform does what is necessary to manage and scale it to provide a given level of service. The Virtual appliances can be classified as instances of PaaS.

Using VCL, Students need not to physically install any specific services, solution stacks or databases on their machine. It provides the images to students where they can simply select these images and use them on a machine provided in a cloud.

- Services
- Solution Stacks
 - Java
 - PHP

- .NET
- Storage
 - Databases
 - File Storage

3. Software as a Service (SaaS)

SaaS is the ability to access software over the Internet as a service. Software as a service has a complete application to offer as a service on demand. A single instance of the software runs on the cloud and services multiple end users or client organizations. Here the best example remote application service is Google Apps, which provides several enterprise applications through a standard Web browser.

VCL allows any of the *software as a service solutions*, virtualization solutions, and terminal services solutions available today. VMWare, XEN, MS Virtual Server, Virtuoso, and Citrix are typical examples. VCL also allows any of the access/service delivery options those are suitable from RDP or VNC desktop access, to X-Windows, to a Web service or similar.

Cloud computing infrastructure models

Cloud computing architects need to make some considerations about infrastructure models when moving from a standard enterprise application deployment model to one based on cloud computing. There are three basic service models to consider in a university based cloud computing, such as Public, Private and Hybrid clouds.

1. Public clouds

Public computing clouds are open to anyone who wants to sign up and use them. Public clouds are run by vendors, and applications from different customers are likely to be mixed together on the cloud's servers, storage systems, and networks. One of the benefits of public clouds is that they can be much larger than a company's private cloud and can offer the ability to scale up and down on demand, shifting infrastructure risks from the enterprise to the cloud provider.

IBM operates a cloud data center for its customers. Multiple customers share the same infrastructure, but each others' cloud is secure and separated as though behind its own firewall.

2. Private clouds

The intention of designing the private cloud is basically an organization that needs more control over their data than they can get by using a vendor hosted service.

Private clouds are built for the exclusive use of one organization, providing the utmost control over data, security, and quality of service. Private clouds typically sit behind the firewall of an organization (enterprise or university), and only people within that organization have permission to access the cloud and its resources.

3. Hybrid clouds

Hybrid clouds combine both public and private cloud models. This model introduces the complexity of determining how to distribute applications across both a public and private cloud. If the data is small, or the application is stateless, a hybrid cloud can be much more successful than if large amounts of data must be transferred into a public cloud for a small amount of processing.

VCL can work on Hybrid cloud model. It can provide services and infrastructure to the students and faculties of single university acting as a private cloud. It can also extend this services for inter university using public cloud. This requires more secure network.

Heterogeneous resource clouds

The main intention of designing heterogeneous cloud in universities is to significantly decrease the configuration scale of the cluster system through consolidating heterogeneous workloads, while increasing the number of requests for parallel workload by provisioning enough resources (e.g., based on Globus, Hadoop, or Condor). For large organization, different utilities often maintain dedicated cluster systems for different workloads. Thus the main challenge is to consolidate heterogeneous workloads of the same organization on the cloud computing platform through VCL.

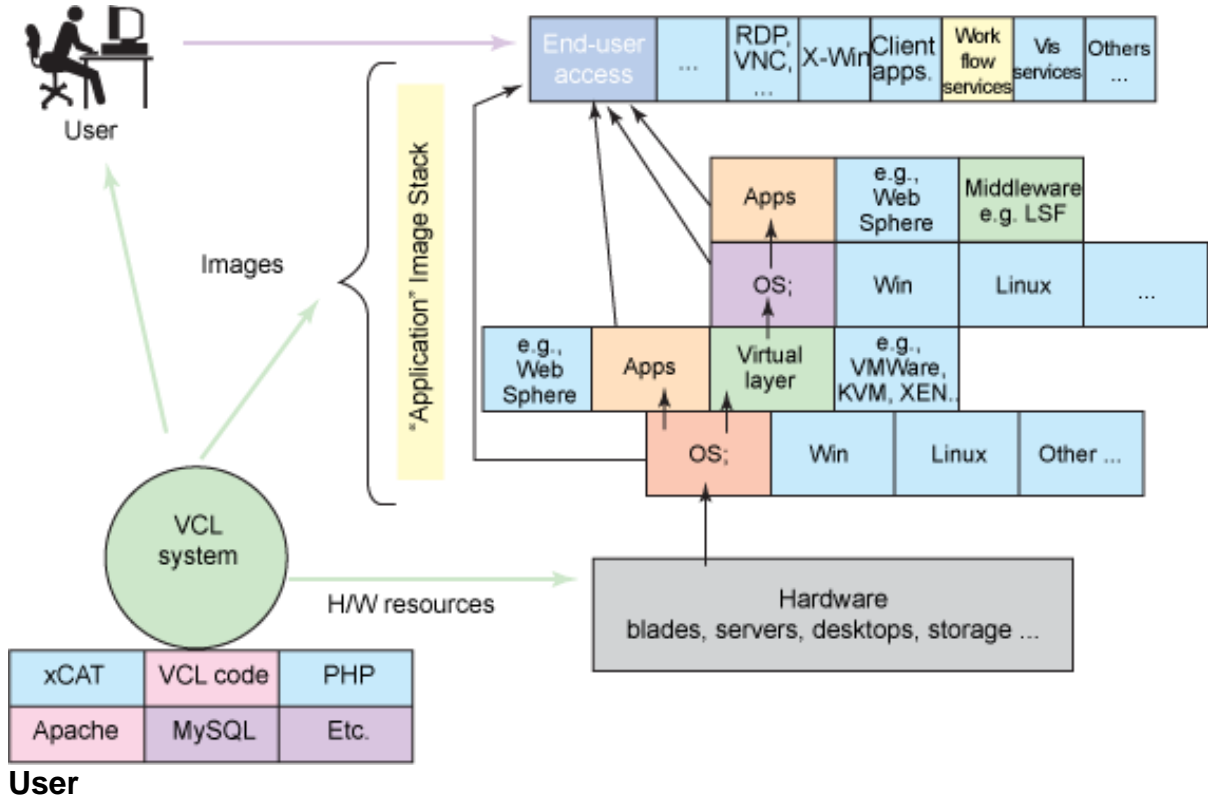
From the perspective of a VCL, it can transform and support any type of environment (as heterogeneous) as long as an image with the appropriate environment manager is available.

High-level architecture of VCL

This VCL architecture mainly is intended for designing and configuring a cloud computing system that serve both the educational and research missions of the university in a very economical and cost efficient manner. VCL delivers a range of functionalities and services that map well onto the cloud computing requirements and its expectations. There are few principal components in the VCL architecture as shown in Figure 2. For more information about VCL and its working model, see the Resource section.

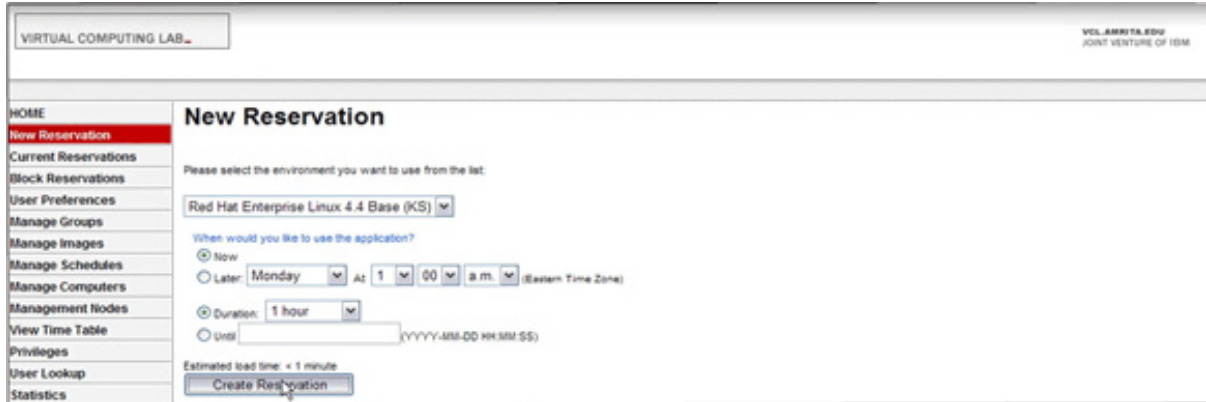
- An end-user access interface (web-based)
- A resource-manager (or VCL manager) which includes a scheduler, security, performance monitoring, virtual network management, etc
- An image repository (or image)
- Computational, storage and networking hardware
- Security

Figure 2. VCL physical architecture



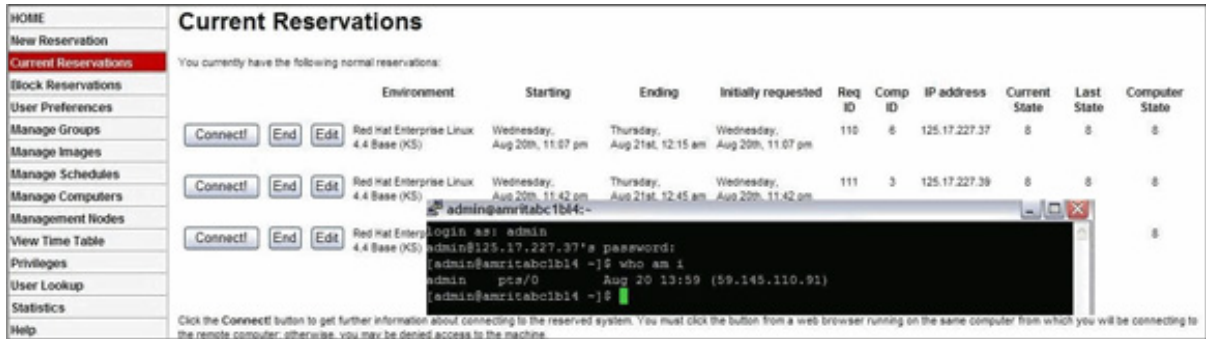
Initially user accesses VCL through a Web interface to select desired combination of application from a menu. See Figure 3. If a user specific image combination is not already available as an *image*, an authorized user can have the flexibility to construct their own image from the VCL library components. The VCL manager software then maps that user request to available software application images and (possibly heterogeneous) hardware resources, and schedules it for either immediate use (on demand) or for later use.

Figure 3. New reservation of resource with desired image



The mode of access to resources will depend on the service offering. See Figure 4. It may range from RDP or VNC type of access to a remote desktop, to an ssh-based or an X-Win access to a Linux service, to Web-based access, and as a proxy access to a computational cluster.

Figure 4. Current reservation and ssh-based connection



VCL manager

The typical job of VCL manager includes checking the environments, managing computers and managing images. VCL manager software was developed by NCSU comprising the following products:

1. IBM xCAT and VM loader

The Extreme Cluster Administration Toolkit (xCAT) is a collection of mostly script based tools to build, configure, administer, and maintain Linux clusters. The VCL used xCAT to load the requested bare-metal image to a blade server.

While the original VCL was bare-metal oriented, today it loads either a VMware-based image or a bare-metal image. The VCL system processes the request. If it does not find an available real or virtual server with the desired image already loaded, it selects any available server meeting the specifications required for that image, xCAT, or the appropriate VM loader, dynamically loading the desired image. Here, the physical machine provisioning happened through xCAT and the

virtual machine provisioning happened through VMware ESXi, VMware ESX Standard server, VMware free server.

If all servers are busy, the Web interface informs the student on the available times using a grid.

2. NCSU middle layer demon service (vcl)

The core part of VCL manager is a perl based VCL demon service (vcl) used to perform the actual provisioning and deployment. Based on the type of environment requested - whether it is a bare-metal image, a lab machine, or a virtual machine image, vcl ensures the image is loaded and makes it available for the requests. Common utilities of a vcl service are:

- Communicate between Web interface and database to get the installation details and process reservation/job assigned by the VCL Web portal
- Initiating xCAT or VMware commands to perform requested operation
- Monitor the image installation procedure and installing requested postscript installation tools
- Maintaining the machine provisioning and deployment procedure
- Configuring and administrating the installed image for the requested use
- Maintaining the installation and configuration time

3. An open source web server (Apache)

The PHP based Web application (deployed in Apache Web server) is the heart of VCL and provides tools to request, manage, and govern all VCL resources. The Web interface allows authenticated users, displays a list of applications they are authorized to use, and allows them to reserve the use of an application either immediately or sometime in the future for a specified length of time. The range of future time and the length of reservation are customizable and can differ based on the user. The major utilities provided by Web interface includes:

- Image creation – This interface allow users to create customized environments.
- Image revision control – This interface provide privileged users to create multiple revisions of same image.
- Manage users – This provides user privilege control, it grants varying levels of control to users through Web interface.
- Manage resource – This interface provides a method to schedule the resources in the pool.

4. An open source data base (MySQL)

The MySQL database to track each server's state, maintains information about each image, and implements a privilege tree.

Image

In VCL, the term *image* is a software stack that incorporates the following utilities:

- Base-line operating system, and if virtualization is needed for scalability, this will allow on hypervisor layer
- Desired middleware or application that runs on the selected operating system
- End-user access solution that is appropriate for the selected operating system

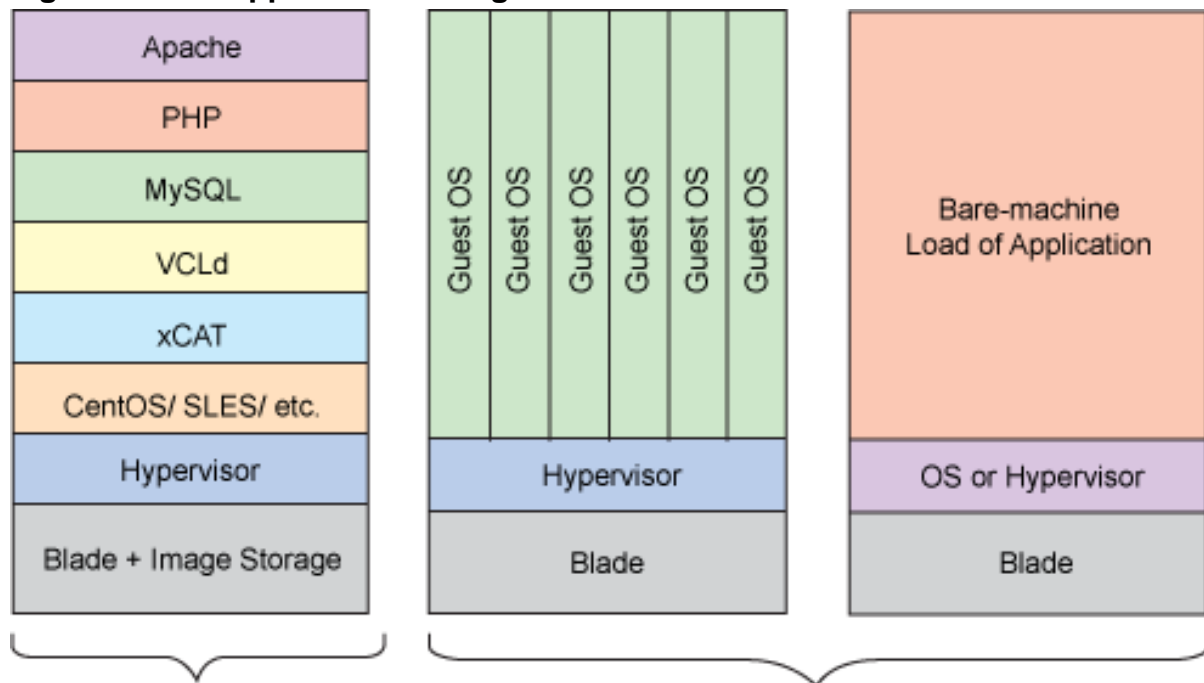
Images can be loaded on bare-metal, or to an operating system/application virtual environment of choice. If the user's desired combination of images is not available, the user has the privilege to construct the images in their own choice from the VCL component library. When a user has the right to create an image, that user usually starts with a *NoApp* or base-line image (Windows XP or Linux) and extends it to the applications.

Computational hardware/network storage

Virtualization completely abstracts the hardware to the point where software stacks can be deployed and redeployed without being tied to a specific physical server. VCL servers provide a pool of resources that are exploited for the users needs. The resources are allocated depending on the particular applications that are to be computed. The storage and network resource are dynamic, meeting both the workload and user demands.

The term *compute clouds* are usually complimented by storage clouds that provide virtualized storage through VCL facilitating the storage of virtual machine images. In VCL, computational hardware and storage can be anything from a blade center, to a collection of diverse desktop units or workstations, to an enterprise server or to a high-performance computing engine.

A typical VCL installation will have one or more blade chassis, usually one of the blades being designated as the management node. Each blade has at least two networking interfaces – one for the public network, and the other for a private network that is used to manage the blades and load images. Storage is attached either directly through fiber or through a network. See Figure 5, below.

Figure 5. VCL Application Storage

Security in VCL

It is difficult to justify, what security means in the context of cloud. The ultimate level of security measures needed for any distributed system comes from both authentication and authorization of services. VCL implemented the following level of securities in their system:

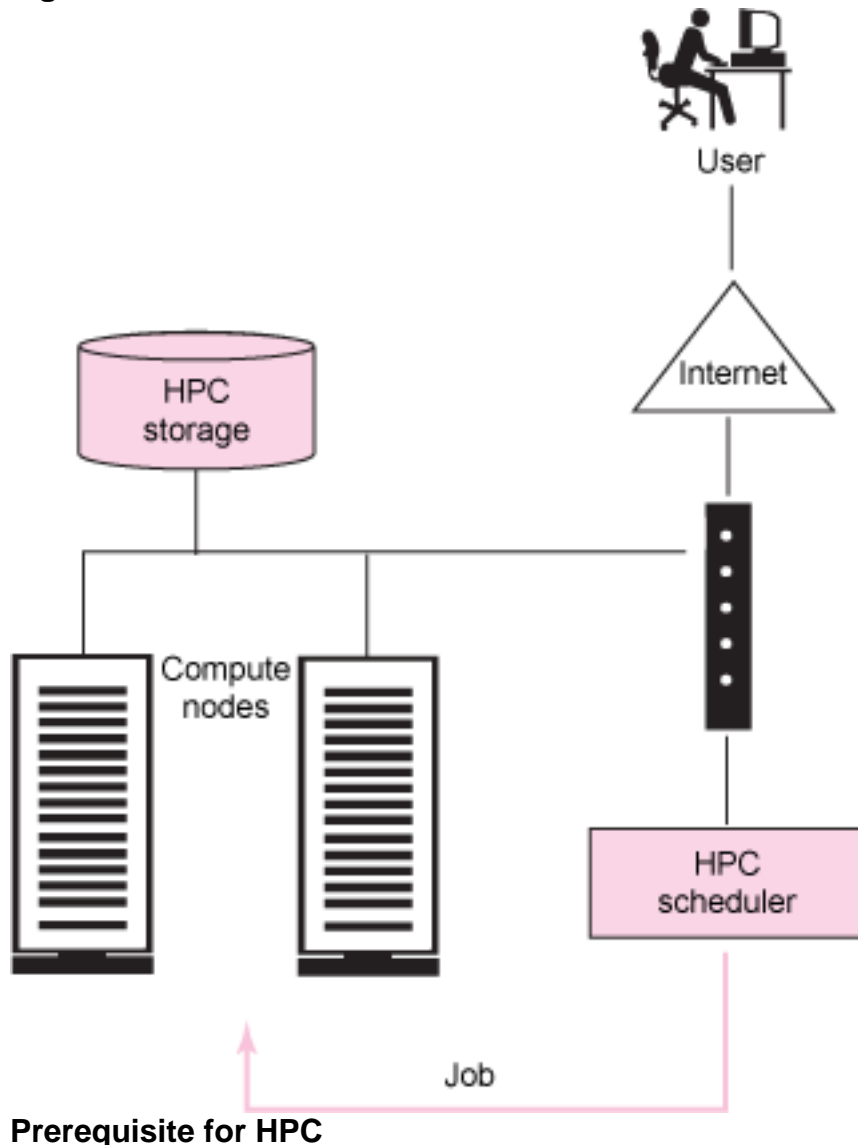
- LDAP based authentication**
 VCL authentication is an affiliation based LDAP service. Based on the user affiliation, VCL supports different LDAP services for separate user access.
- Environment level authentication**
 This mode of authentication will vary depending on the environment. It is usually determined by the image creation time. In Windows, it will create a single one-time account that gets created at reservation time and will expire after use. In a Linux environment, it can make use of either existing authentication infrastructure or can also use standalone account mechanism.

Apart from these, if a user is authorized and allowed to make a VCL reservation, VCL IP-locks the provisioned environment to end-user IP address using OS level firewall.

High Performance Computing and VCL

There are mainly two implications for the High Performance Computing (HPC) level of machine utilization in universities. First, the need for HPC machines in universities - it is mainly to solve/compute demanding problems. Second, it is very hard to accommodate the hardware resources for increasing requests from VCL. The basic working model of VCL on HPC services is fairly simple. See Figure 6, below. To know more about VCL HPC and its usage, see Resource section.

Figure 6. Basic model of HPC in VCL



- Network switch – A new private network for message traffic using NIC

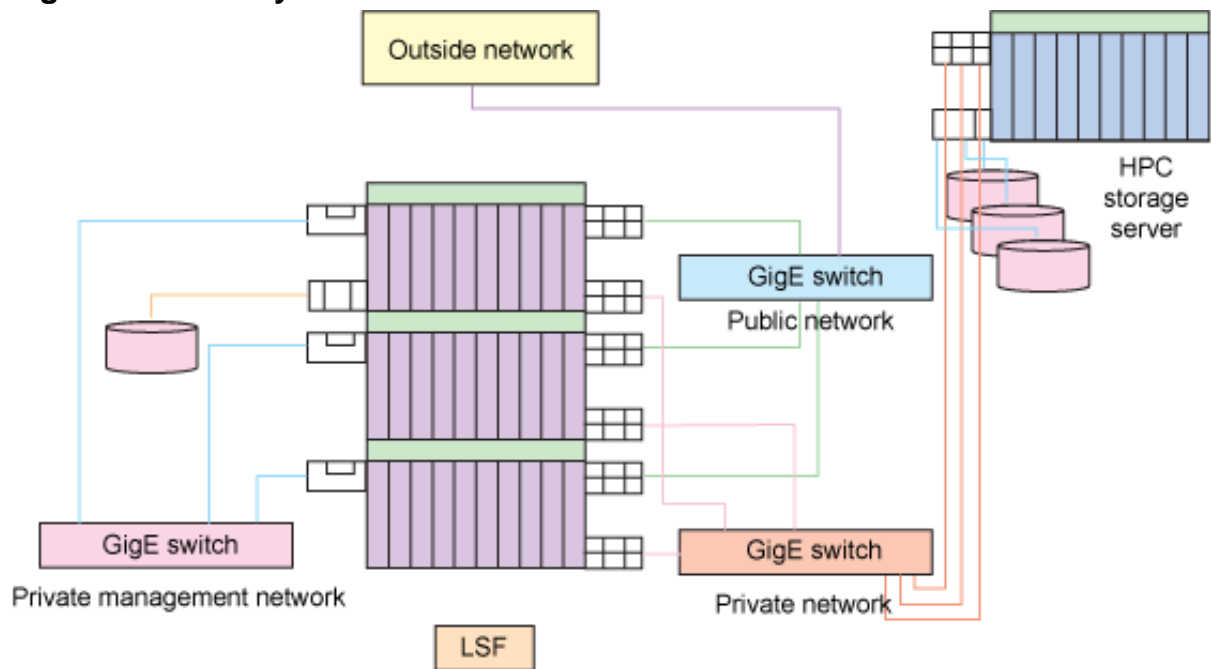
that would be used for public network user access.

- You need to configure Virtual Local Area Network's (VLAN) on one chassis switch module. One for public internet access and one for private message passing interface.
- VCL management node configured blade VLAN based on image metadata.

Working method

The basic working model of HPC in a VCL is as shown in Figure 7. Under VCL control, xCAT loads HPC computational images to idle blade nodes, and the VCL control software adjusts VLAN settings on the chassis Ethernet switches, to connect the servers to private HPC networks. In an HPC environment, VCL provides public access only through login nodes. The master HPC login node image includes components of the HPC scheduler. Currently, Load Sharing Facility (LSF) is used in VCL (like platform computing). Each HPC client image has access to a large amount of storage (in terabytes), as well as user home directories and HPC backup storage. When an HPC image is loaded, the VCL manager scheduler recognizes it and begins to assign it work.

Figure 7. Basic layout of Blade Server in VCL HPC



The integration of HPC in VCL significantly increases resource utilization by the reuse of blade servers. This method allows the infrastructure to be shared among user requests, which leads to a greater availability of resources.

Benefits of using VCL in labs – a cloud solution

We have identified some major capabilities of VCL cloud computing with help of NCSU VCL lab performance through diagrams to explain major benefits. See Resource section. In universities, users are typically students and faculties. Cloud computing systems serving these users within a university environment must at least provide the following capabilities:

- Services and support to a wide range of users.
- A wide-range of course materials and academic support tools to instructors, teachers, professors, and other educators and university staff.
- Research level computational systems and services in support of the research mission of the university.

With these requirements, the major challenges of planning a cloud computing solution in a higher educational, research-oriented institute involves following factors:

- Excellent resource utilization depending on different user demands
- Variety of diverse service environments
- Operating cloud infrastructure as an economically viable model

In universities the usage of resources will vary depending on the academic calendar. Demand for resources will be more during assignments and year-end time. The research projects and other research oriented activities are active throughout the year. So for a university based cloud computing system to be economically viable, it requires a proper scheduling mechanism to monitor demand and allocate the system resources. VCL provides good scheduling mechanism to identify the ebbs and flows of campus activities.

Here, by the observations and insights from the VCL environment at NCSU, the important inference that we can identify in VCL is that, with the help of desktop and HPC utilization, VCL provides efficient utilization of the computational infrastructure in NCSU. Also, using the VCL blades for both HPC and VCL desktops provides economical services with optimum use of resources.

We can thus conclude that NCSU VCL is an open-source Web based system used to dynamically provision and broker remote access to a dedicated computer environment for a user. VCL cloud provides exceptional computing power through a unique Open Software and Hardware Solution to run and host all university projects and learning programs.

Acknowledgements

The [VCL Paper](#) provides information on the use of VCL in universities. I wish to thank **Mr. Aaron Peeler**, Program Manager and core member of VCL development team, for providing us with support to write this article and offer suggestion/comments about VCL and its working model.

Resources

Learn

- For information on concepts of VCL, installation details and the mailing list, see [Open source VCL APACHE](#) incubator.
- The [Cost Effective VCL](#) will provide information on the performance of VCL in NCSU universities.
- The [Hadoop core](#) Web site is the best resource for learning about Hadoop.
- Here you will get the [concepts of VCL](#) and its detailed working model.
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