Developing the Delivery of Complex Virtual Computing Laboratory Resources for Distance Learning Opportunities for Anglia Ruskin University’s Regional and International Partners

Abstract

The purpose of this research is to further evaluate and analyse the use of virtualisation and associated cloud technologies to deliver traditionally resource intensive complex computing modules as a completely virtualised distance learning experience.

The intention is to build upon our established body of research to develop the concept of the Laboratory as a Service (LaaS) with complex real world system and networking scenarios which would otherwise require significant man hours to develop as physical resources.

Two core areas of case study focus were implemented and analysed by volunteers from geographically dispersed locations against a set of evaluation criteria to determine the more effective solution for deploying the LaaS.

Both VCL and Netlab solutions deliver an automated and self-maintained virtualised remote computing environment to cater for students’ needs with very little administration.

Future plans are to extend VCL functionality to allow the creation of more complex sandboxed environments and utilise external distributed cloud resources.

Keywords

virtualisation, virtual, laboratory, web, complexity

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Background
Delivering a complex computing resource-based module may historically have required specialised software on dedicated computing platforms. However, the delivery of distance learning laboratory-based resources enhances the traditional use of teaching space and data centre resources. This means that resources could be implemented in a virtual environment utilising a more generic structure and facilitating easier sharing between modules. This has a beneficial impact on the requirements for generic physical computing resources.

Aims

• To develop a sample distance learning based module utilising a complex IT system model, which could be delivered to learners irrespective of time zone or geographical location.
• To trial delivery as an additional course with a minimum of two partners (ideally one regional and one international) to assess the impact and practicalities of traditionally resource intensive modules utilising a complex IT model, delivered entirely by distance learning using a virtual laboratory system.

Longer Term Aim
• Continuing long term goal of developing a part-time distance learning BSc Computer Science as well as leading a contribution to developing distance learning aspects for Masters and Foundation Degrees.

Virtual Laboratory
According to the Oxford Dictionary the definition for a laboratory is ‘a room or building for scientific experiments, research, or teaching, or for the manufacture of drugs or chemicals’. Computer Science students need equipment such as networked computers, routers, switches and specific software applications so that the teaching process can be as productive, fruitful and realistic as possible (Machotka, Nedic & Gol, 2007).

The use of a physical computer laboratory, until recently, was the only way to apply, in practice, the theoretical knowledge gained in the classroom. This, however, caused limitations such as time and space restrictions, supervision, high costs for maintenance and scheduling for the use of the resources (Nedic, Machotka & Nafalski, 2003). All of these can be avoided with the implementation of a distance laboratory solution, which is a system that provides ‘efficient user operations, machine and platform independence, secure operations, graphical user interface capabilities, high processing bandwidth, and low cost maintenance’ (Steidley & Backnak, 2005).

Ma and Nickerson (2006) concluded that the uniting factor between all variations of these systems is that they ‘are characterised by mediated reality’ and ‘experimenters obtain data by controlling geographically detached equipment’.

According to Wiseman et al. (2008), a virtual laboratory is a ‘facility where students can access real laboratory equipment remotely’. However, new technologies have furthered the above statement and have enabled the manipulation not only of real-world equipment but of its virtualised analogues as well, which gives a more specialised meaning to the term ‘virtual lab’. Leitner and Cane (2005) support this by saying that ‘any local computer hosting a simulation’ is considered a virtual lab. They elaborate even further and use the term to describe a computational grid, used for solving computational problems with geographically distant resources.

Growth of Virtual Labs
The growth within organisations of new computing paradigms such as ‘Virtual Desktops’ has allowed the concentration of IT resources centrally and the distribution of mobile computing platforms (smartphone, tablets, etc.) where users are able to access their work desktop from anywhere, anytime where an Internet connection exists.

The application of virtualisation for delivering quality distance teaching allows academic staff to offer customised desktops to suit the learner’s needs based on course requirements. There are differing definitions of virtualisation which include:
‘abstract computer resources which are only virtual software versions of something rather than really existent’ (Michocka and Shwartzman, 2008).

‘virtualization [which] enables one server or computer to act as many’ (Robb, 2008).

The traditional view of the computing device involves layered software such as the operating system and applications running on the computer hardware with storage media such as a hard disk.

Figure 1 – Conventional Computer Hardware versus Virtualised Hardware (derived from VMware 2)

Virtualisation software, called a hypervisor, allows the user to create virtual machines and runs between the hardware and the individual operating systems as shown in Figure 1, labelled VMware. So instead of buying (for example) 10 computers to do different tasks and have most of them with unused memory and processor power, one only needs to buy one or two really powerful computers and run hypervisors. This allows the creation of virtual machines in software, to efficiently consume its allocated hardware resources only, thus retaining unused hardware for other virtual machines usage.

Devin (2010) describes the relationship between hardware and software using a metaphor in which hardware can be viewed as a wardrobe which, while it can be built in various sizes, each wardrobe holds a finite amount of storage. Software, on the other hand, is what is stored in the wardrobe — clothes, shoes, bedding and towels, etc. Many items can be forced into a large wardrobe but doing so makes it cluttered and hard to use. However, if a number of smaller wardrobes were used, space would be wasted because it is unlikely that each wardrobe would be completely filled.

Using this metaphor, virtualisation can be compared to a wardrobe organiser system, in which adding a clothing rail to hang dresses and blouses on, and a shelf or two underneath that for shoes, with additional shelves to one side for trousers, etc., makes better use of a finite space.

Complex Laboratories

Whilst accessing a virtual desktop from a computing device is straight-forward, most computing and engineering style applications require the interaction of two or more computing devices. In essence this means for the complex virtual laboratory a minimum of two networked virtual machine or virtual desktops together to provide some form of IT function. In fact any learning solution offered by a virtual laboratory will be much more sophisticated.

In a physical computer lab, to set up many of these complex IT configurations there is a requirement for a large number of physical devices, which may need to be reconfigured within a short time frame depending on the requirements of other scheduled users of the laboratory (space and physical storage requirements may also be considerable). One solution might be to provide virtualisation services within a physical computing laboratory but this does not address the distance learning component and building these scenarios can require a large amount of local storage.
Solution for Complex IT Virtual Laboratories
The aim would be to provide functionality to offer a remote distance learning tool in the most beneficial way for the students’ learning experience whilst maintaining ‘state of the art’ equipment and the use of relevant IT laboratory configurations.

Another current computing concept is the cloud paradigm, where effectively all IT services are offered ‘as a service’ irrespective of geographical location. In the context of distance learning, the offering would be the ‘Laboratory as a Service’ (LaaaS) which would provide remote access to virtual resources that can be managed as required. For students to use these types of facilities, virtual images could be stored for student progression or reverted to previously stored states.

Essentially there are 3 main scenarios
- Simple Virtual Laboratory (Single Images)
- Hybrid Virtual Laboratory (Layered/‘Nested’ Images)
- Complex Virtual Laboratory (Multiple Images)

Simple Virtual Lab
In this scenario a virtual laboratory offers users a single virtual machine of choice by reservation depending on the module/pathway undertaken. This virtual machine is then accessed in much the same way as remote access to a conventional computer. To offer the complex laboratory scenario, a user would create two instances of different virtual desktop, and have them interact together. This is a complex task which requires the resolution of some security issues as well as configuration knowledge to maintain connectivity and system interactions.

In terms of the previous wardrobe metaphor, consider this as two or more wardrobe organisers in different rooms where the user has to walk between, find and coordinate the clothes themselves.

Hybrid Solution
The hybrid solution relies on a single virtual machine which has a group of virtual machines configured as the complex IT system within itself. This single virtual machine is then accessed as before with normal remote access techniques. Essentially a group of virtual machines are created and interconnected on a single ‘nested’ computer platform. The single platform is then transformed into a virtualised image to allow it to be commissioned/decommissioned as a virtual machine as in the simple virtual lab.

Think of this as a wardrobe organiser within a wardrobe organiser where one must go through two different sets of organiser to find the clothes so everything becomes much slower and takes longer to find. In addition, complexity extends to maintaining the state of the students’ lab, much like having to remember which clothes went where within the two levels of virtualisation.

Complex Virtual Lab
In a complex virtual lab, individual virtual images are created in a secure (sandboxed) environment which only the user can access via a web-based user interface or equivalent. The virtual machines are created or deleted on demand by some form of scheduling function (which only uses the actual resources required for the duration of the laboratory booking) and linkage between the various components is provided by the user interface.

Each virtual component can only access others connected to its group and remains secure from other operational environments. It has the advantage of being customised to the learning experience by providing links to all the resources being accessed and no user setup is required. Effectively this is single access, restricted to a group of wardrobe organisers to which only the user has a key and the private inventory to know where everything is.

Methodology
An experimental approach was used to examine two of complex virtual laboratory model approaches:
- Investigation of an Open Source (Apache Foundation) Virtual Computing Laboratory (VCL) in a network distributed environment for commissioning of reusable operating resources, providing a cloud computing based solution for network security laboratory teaching scenarios based on both the simple and hybrid laboratory models.
Use of a proprietary off-the-shelf remote laboratory system, such as NDG’s Netlab, to offer the Complex Laboratory Model for complex IT systems, such as VMware VSphere courses, which can be easily deployed as virtual-based solutions on demand, forms the basis for new modules on the Computer Science pathway.

Two areas of technical relevance that occur with virtual labs that were considered in the approach are:

- Persistence – maintaining the state of the learner experience with the virtual laboratory (i.e. allowing students to resume sessions by saving the state). This is akin to keeping a record of where clothes have been moved to for the next time you visit the closet.
- Snap Shots – the state of the laboratory is not saved, it reverts at the end of the session to the previous state. This is akin to making sure clothes go back exactly to where they were stored before and in exactly the same condition.

**Complex Laboratory Delivery**

The first experimental investigation utilised past work from Winckles and Spasova (2011) and continued the investigation of the open source VCL platform (Figure 2). This involved some student projects evaluating how modules from the Information Security course could better utilise tools for security investigations on vulnerable systems. VCL could successfully be used to deliver single virtual desktops (Figure 2) but students had to facilitate the communication between the two or more virtual machines. For hybrid delivery, customised nested virtual machines were created.

![Virtual Computing Laboratory (VCL) – Simple Virtual Laboratory Scenario](Derived from Jeries, 2011)

For the second part of the research experimentation, the Netlab platform (Figure 3) was used as a demonstration capability for a VMware vSphere v4.1 (Installation, Configuration and Management) short course which will form part of a new Level 3 module, *Network and IT Operations*. Students and partners accessed the laboratory exercises online via a topology-based web interface (Figure 3) and kept a log book of laboratory exercises and support issues whilst undertaking complex labs with a particular emphasis on how both persistence and snap shots affected their ability to use the labs effectively. A post laboratory experiment questionnaire was also completed.
Questionnaire and Logbook Results
A total of eight individual students and partner institutions were involved in the research, resulting in over 200 hours of online activity between those who responded to the survey, with some very positive results and useful feedback in some key areas to guide future development.

Students felt that errors that occurred in the virtual laboratory led to reliability issues, necessitating that the laboratory is fully tested before student delivery. Also raised were issues relating to fixing a configuration problem half-way through a set of laboratory exercises, which suggested that very clear, concise instructions are needed when developing laboratory exercises, especially when using third party courseware.

Conclusions
Both VCL and Netlab solutions are capable of delivering an automated and self-maintained virtualised remote computing environment to cater for students’ needs with very little on-going administration.

Whilst VCL provides a highly scalable, flexible and very cost effective solution, it is limited in the complexity of the solutions potentially offered. If a simple laboratory implementation is used then students are required to configure their environment to facilitate communication between the two or more virtual machines in use.

Netlab provides a more managed solution better able to provide the complexity and flexibility that more advanced computing courses may require. The problem with Netlab is the licensing model which requires a much larger investment to support a greater number of simultaneous students who can take advantage of the persistent storage options.

Future Work
- The development of the open source VCL platform to leverage the advantages that Netlab offers.
- The development of external resources using cloud technologies when the institution’s own resources are insufficient.
- The development of secure group of virtual resources to offer a more managed experience for the student
References


