Undergraduate Engineering Computing Virtualisation

W. Spencer Smith

Director, Engineering 1
Computing and Software

Thomas E. Doyle

Assistant Professor, Engineering 1
Electrical and Computer Engineering

Michael D. Curwin

Manager, Information Technology
Faculty of Engineering

McMaster University, Hamilton, Ontario, Canada

smiths, doylet, curwinm@mcmaster.ca

Abstract

A new virtualised computer lab has been implemented for Engineering 1 students at McMaster University in Hamilton, Ontario, Canada. The laboratory infrastructure was deployed in two stages with the goal of providing a user experience that was indistinguishable from a traditional computing lab. The first stage was a one-to-one mapping between 56 thin clients and 56 Blade servers using the Teradici communication protocol. The second stage was a true virtualised platform with 56 thin clients and 3 Blade servers using the PC-over-IP (PCoIP) communication protocol. We surveyed several laboratory sections on usability and user experience of a popular visual programming development environment and a solid modelling CAD package. Students were asked to compare their current “workstation” performance against previous performance and the performance of other computing facilities on campus. When conducting the survey, students were not aware whether the machine they were seated at was a stage-1 or stage-2 configuration. The results show the majority of users believe the stage-2 virtualised implementation is as good or better than stage-1 or other facilities on campus. We have also compared resource requirements for the traditional computer lab and the virtualised computer lab. Operational resources are reduced by several orders of magnitude and administration has become significantly more efficient. In the current third stage of deployment we will be allowing students to connect to the virtualised laboratory from outside the physical lab. Our paper will cover the motivation and benefits for developing this laboratory, the structure of our virtualised laboratory, the student survey results, and the calculations of operational savings using this new laboratory model. The implementation of a virtualised laboratory structure provides new flexibility on the accessibility to computing laboratories, which we believe will be of interest to all levels of engineering education.

Keywords: undergraduate laboratory, software virtual-

ization, educational computing infrastructure, innovative educational methods

1 Introduction

Virtualisation was developed to support the complete instruction-by-instruction execution of one computer system on a different computer system [1]. The objective of virtualisation was to provide operating system and application engineers a test environment without requiring the physical machine. Since then virtualisation has progressed to where it is currently not uncommon to find virtualisation software on personal computers for concurrent operation of different operating systems and applications. This capability is extended across data networks using solid-state thin-clients or software clients to create a virtual computing environment; the Virtual Desktop Interface (VDI). At McMaster University we have developed the first virtualised computer lab on campus and the world’s first virtualised solid-modeling CAD laboratory. Virtualisation offers to revolutionize the traditional undergraduate engineering laboratory by expanding accessibility beyond the physical lab room while dramatically reducing the overall operational resources.

2 User Experience

The benefits of virtualisation, such as easier lab management, reduced energy costs and dynamic desktop management, are meaningless if the user experience is poor. Our goal for the VDI lab was for the user experience to be at least as satisfactory as for a traditional, nonVDI lab.

The implementation of our lab provided an excellent opportunity to measure the impact of virtualisation. Given that virtualisation of 3D modelling software was pushing the limits of what can be accomplished with today’s VDI technology, we developed a conservative plan where the initial phase of the lab implementation was closer to a traditional lab. In the first phase the lab con-

In the last week we have made changes to the lab computers, such as upgrading the firmware. How would you compare the speed (responsiveness) of the machine you are sitting at to that of previous weeks?

The speed over the last week has been $\begin{pmatrix} \text{worse} \\ \text{same} \\ \text{better} \end{pmatrix}$ as that of previous weeks.

Figure 1: Comparison to previous weeks.

sisted of a one to one mapping between thin clients and servers, using hardware Terradici cards to implement the PC over IP protocol. This environment operated successfully for several months before we began the transition to a true VDI lab, where we replaced 56 IBM HC10 servers with 2 IBM HS22 servers. We did the transition of the lab to a true VDI solution gradually so that we could measure the differences between the two designs.

At an intermediate point in the transition to the true VDI lab, when we had 22 virtual machines and 34 traditional machines, we conducted a survey of the students that use the lab. This allowed us to determine whether there was a significant difference in the user experience between VDI and nonVDI. We conducted surveys of students in two classes: a 3D solid modelling class and an introductory programming course. In the 3D modelling class we had 16 respondents on VDI machines and 19 on nonVDI machines. For the programming class we had 14 respondents on VDI machines and 14 on nonVDI machines.

2.1 Compared to Previous Weeks

The first question on our survey (Figure 1) asked the students to compare the speed of their machines to the past performance they had observed in the lab. The students were not told whether they were on a VDI machine or not. In fact, they were not told anything about the changes in the lab other than there had been a firmware upgrade.

The results for the question posed in Figure 1, normalized by the number of respondents, are summarized in Table 1. The results for the nonVDI machines, which are essentially the same for both classes, are as expected, given that the students were working on the same machines as they had been for previous weeks. The majority of the students (over 50%) thought the performance was the same as for previous weeks and very few (between 5% and 7%) saw the performance as worse. Interestingly, many students (over 35% in both classes) saw an improvement in performance, when no improvement actually existed. The explanation for this is the anchor effect, which was first discussed by Tversky and Kahne-

How would you compare the current performance of the computer you are sitting at to computers in other labs on campus?

The performance of the computer that I am currently sitting at is $\begin{pmatrix} \text{worse} \\ \text{same} \\ \text{better} \end{pmatrix}$ as that in other labs.

Figure 2: Comparison to other labs.

man (1974) [2]. The students were told that there was an upgrade in the lab, so they were biased toward seeing an improvement.

Table 1: Compared to previous weeks.

	3D CAD		Programming	
	VDI	nonVDI	VDI	nonVDI
worse	0.50	0.05	0.29	0.07
same	0.31	0.58	0.71	0.57
better	0.19	0.37	0.00	0.36

The results for the VDI machines show a difference between the 3D CAD and the programming courses, with less positive results for the 3D CAD course. For the 3D CAD course 50% of respondents felt the new lab was the same or better, versus 71% of respondents for the programming course. The less positive results for the 3D CAD class are not surprising, since 3D graphics are notorious for being challenging to virtualise. To explore the student opinions further we also asked them to compare the new lab to other labs on campus.

2.2 Compared to Other Labs

The second multiple choice question on the survey is shown in Figure 2. This question was the same style as the first, but instead asked the students to compare the performance of the computer they were sitting at to the computers in the other labs on campus.

The majority of students, whether they are using a nonVDI or VDI machine, think favourably toward the new lab. Even for the most challenging case, 3D CAD with VDI, almost 70% of the class felt the new lab was the same or better than other labs they had experience with. Part of this positive response is likely due to the layout of the lab, which has a novel elliptical shape, and large computer monitors.

If we were to do the survey again today, we would expect an even more positive result, since we have taken steps to improve the performance of the VDI lab since its initial implementation. For instance, an additional server was added to take on some of the load, more

What do you (^{like}_{dislike}) about using the ETB/118 computer lab? For instance, the software options, performance, ambiance, acoustics, space, etc.

Figure 3: Positive and negative comments

memory was added, and the software controlling the VDI desktops (VMWare View) had several parameters tweaked to promote performance. We are confident that the students are satisfied with the current implementation of the lab, since over several months of 9 hours of usage per weekday, we have not heard any performance related complaints.

Table 2: Compared to other labs.

	3D CAD		Programming	
	VDI	nonVDI	VDI	nonVDI
worse	0.31	0.00	0.07	0.07
same	0.5	0.37	0.51	0.14
better	0.19	0.63	0.43	0.79

In addition to the quantitative information listed above, the students were also asked two qualitative questions, as summarized in Figure 3. The majority of the written comments made on the survey were positive. With respect to performance, several students commented on the quality of the computers, the speed of the computers and the lack of ambient computer noise. The last advantage in particular was made possible by our use of a client server model for the lab, since this allowed us to use solid state thin client computers, which do not generate any noise.

With respect to negative comments, there were some students that thought the computer speed needed to be improved, but many comments focused on issues not specifically related to the VDI design. For instance, the students disliked such things as the policy of no food or drink in the lab, or how far the lab is from the residences. VDI may be able to address the second negative comment in the future, since we are hoping to soon make the virtual desktops available to students even when they are outside of the physical lab. The main challenges for accomplishing this are not technical, but rather related to licensing of the desktop software.

3 Architecture

Initial timelines for construction and implementation of the computer lab allowed for only three potential configurations using thin client computing devices. The first

two options were fully software based remote connection protocols (ICA and RDP). Neither were found to be suitable from a usability perspective (end user reviews revealed performance flaws). The third solution was a hardware based model that was ultimately selected for implementation as an interim solution.

3.1 Phase 1 Implementation

The lab implementation proceeded with the use of Devon IT TC10 thin client devices. These devices are zero client machines that all contain PC over IP (PCoIP) embedded processors. For each thin client that was used within the lab, a dedicated blade server was also implemented in the server room. Each blade server also contained a PCoIP embedded processor, which created a full end-to-end hardware solution for each client. The final result of this first phase was a clean front end user solution with a very resource intensive server side. This implementation also allowed for the upgrade flexibility of moving to a software based solution that was planned for phase two. Phase one of the implementation was deemed a success based on user experience. With the first phase being a hardware based solution there was little surprise on the success of the user experience since this emulated a traditional desktop computing model. Given that the client sat in the lab and the processing hardware or workstation sat in another location (i.e. the server room), the only real concern was bandwidth consumption and its impact on the other users in the building, however, preliminary testing revealed that all bandwidth consumption had no negative impact to the other users. The implementation of Teradici based thin clients in the lab poised everything for the second phase transition to a fully software based model. The use of this specific hardware at the time of implementation was by design (with the intent of moving to a software based solution). As mentioned previously however, no appropriate software based solution existed at the time of the initial implementation. With the official release of VMware's View 4 client (approximately two months after our initial implementation), a software based solution existed with the use of PCoIP embedded within the software client itself.

3.2 Phase 2 Implementation

The phase two transition was a staged approach. Initially four clients were moved to the software based solution, followed by approximately one third of the lab (22 clients). Keeping in mind that the lab migration was a live process (since the lab was in use daily), this staged approach was necessary to ensure that the facility continued to function. The final stage of implementation for this phase was the migration of the remaining clients to a fully software based VDI solution. The end result was

56 thin client workstations connecting to pools of virtual machines on three dedicated servers. This resulted in the reduction of 53 servers and 3 additional chassis.

4 Power and Cooling Savings

The transition to thin clients from a traditional computer lab resulted in significant savings in operational costs for our phase one implementation. Further cost reductions were realized with the phase two transition through the removal of significant amounts of hardware in the server room. Overall there was a 91% power reduction realized while the machines were in use and an 88% power reduction realized when the machines were idle. This data was a comparison between the previous (traditional) computer lab and the current VDI (software based) computer lab. It bears stating that such significant results in power savings has generated a lot of interest in this computing model, and that future labs within our purview will definitely be constructed or refreshed based on this new model.

The data shown in Table 3 is the raw data compiled on both labs. Monitors were excluded from all calculations in order to keep the comparison as simple as possible and to do a true “apples to apples” comparison of the computers (or more accurately, the computing devices). An additional standard computer workstation was also measured in order to provide a modern benchmark (since the old computers that were removed were in excess of four years old). Figure 4 shows a graphical representation of all compiled data. While significant savings were realized on power consumption from the computers themselves, additional power savings have also been realized through cooling requirements. With the general knowledge that one watt of power consumed creates approximately one BTU of thermal energy, it was fair to state that most of the same power savings were also realized in our cooling needs. Exact thermal measurements have not yet been completed. Once compiled, this data and the power consumption data will be used to provide monetary numbers.

5 Management

Management of the software VDI implementation is vastly improved as compared to that of a traditional computer lab. Software images for workstations can be prepared weeks or months in advance and implemented or enabled seconds before the start of each class. Maintaining multiple images is also possible, so that one class can use image A and image B can be enabled “on the fly” during the time lapse between classes. This allows for specific software to be available to one class and not

Table 3: Power consumption data (Watts)

Old Lab - IBM Desktop Workstations - Intellistation Z Pro		
	With Load on Machines	No Load on Machines
56 Lab Machines	22,512	14,504
Notes:	56 units X 402W	56 units X 259W
Server Room Power Consumed	N/A	N/A
Totals:	22,512	14,504
New Lab - Phase 1 - 56 E-Class Blades + 56 Thin Clients (Hardware based VDI)		
	With Load on Machines	No Load on Machines
56 Lab Machines	896	896
Notes:	56 units X 16W	56 units X 16W
Server Room Power Consumed	6,744	5,556
Notes:	4 Chassis X 1686W	4 Chassis X 1389W
Totals:	7,640	6,452
Comparison PC - Not in Lab - HP Z400 Workstation		
	With Load on Machines	No Load on Machines
56 Machines	9,520	5,712
Notes:	56 units X 170W	56 units X 102W
Server Room Power Consumed	N/A	N/A
Totals:	9,520	5,712
New Lab - Phase 2 - Three H-Class Blades + 56 Thin Clients (Software Based VDI)		
	With Load on Machines	No Load on Machines
56 Lab Machines	896	896
Notes:	56 units X 16W	56 units X 16W
Server Room Power Consumed	1086	911
Notes:	1 Chassis + 3 Blades	1 Chassis + 3 Blades
Totals:	1,982	1,807

the next, or allows for special computer configurations for class testing (such as disabling internet access to the computer.

Moreover, with the use of VDI, issues such as viruses and workstation corruption have been greatly reduced. Patch management is handled centrally for all machines and can be rolled out at any time without impact to the users. When viruses or corruption is reported, the virtual machine is simply deleted and a new virtual machine is provisioned automatically while the user continues to work.

With regards to maintenance, new images can be deployed during working hours without impact to the users. Likewise, any server maintenance can be accomplished by migrating users and virtual machines to another server as they work (without interruption). Once the assigned server is free of all virtual machines, the server is taken offline, maintenance work is performed, the server is brought online and users are migrated back to the server resource. All of this is done without any affect or downtime to the user.

Figure 4: Power consumption comparison - Traditional vs. Hardware VDI vs. Software VDI

6 Discussion and Conclusion

Through development of our virtualised computing laboratory we have received user feedback and experience that is very positive. As interaction with CAD graphics create the most data, where bandwidth is the limiting factor in VDI performance, the positive user response represents a significant benchmark. Upgrades to the virtualised system continue to improve the experience and permit expansion to the third phase for external lab access.

Required operational resources are dramatically reduced by requiring 91% less power than a traditional computing laboratory, the efficiency of maintenance is greatly improved, and the flexibility of configuration exceeds the traditional laboratory.

The success of this new undergraduate computing laboratory is a model for future computing labs on McMaster campus and we anticipate will be of interest to other engineering schools.

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