A Virtual Solution to a Real Problem: VMware in the Classroom

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Over the past few years we have witnessed rapid advancements in ICT, which in turn has led, in the industry, to a staggering growth in the number and diversity of computer and networking solutions. As a result, academic institutions and professional training organizations face serious challenges in exposing students to many different computing environments while making efficient use of limited resources. To put it bluntly, how do we easily provide people with the practical experience of working with different operating systems, server applications, switches and routers?

For a number of years, tutors at the Christchurch Polytechnic Institute of Technology (CPIT) have been using VMWare for the teaching of Microsoft, Linux, Netware and other operating systems as well as various associated technologies. The use of VMWare allows students to complete exercises, laboratory work and practical projects involving multiple servers in multiple networks without having to leave the physical confines of a single computer. While William McEwan (2002) documents the use of virtual machines, its origins and uses in the teaching of Unix and Linux courses, this paper extends this to other operating systems and moreover shifts the focus to the supporting infrastructure required in order to extract the maximum benefit from this virtualisation of machines, devices and storage media.

This paper discusses one response to the dilemma of needing to expose students to a range of rapidly evolving computing technologies while ensuring that costs are kept low and that the supporting infrastructure is reliable, robust and not easily compromised in one way or another: in short, a solution that delivers to students and staff alike, a safe, scalable and flexible learning environment.

1. INTRODUCTION

Educational institutions around New Zealand and indeed the world face the challenge of exposing their students to a range of technologies, when these institutions have access only to a limited pool of resources and the technologies themselves are undergoing rapid and profound change. They splinter, connect, diversify and fuse in ever-increasing permutations for different situations and environments. How are tertiary institutions to respond to this complex mesh of technologies and offer their students appropriate first-hand practical knowledge and experience? This paper considers one solution to this problem: the use, in the classroom, of virtual hosts, each of them a fully fledged computer, within the context of a physical support infrastructure that is necessary to ensure the most effective use of virtual environments.

2. BENEFITS OF VIRTUALISED ENVIRONMENTS

The most prominent brand name name in virtualisation is undoubtedly VMware, but a range of other similar and not so similar products exist, both in the Windows and Linux environment (McEwan, 2002 and kernelthread.com, 2004). One product that competes directly with VMware for market share and that has grown in popularity in recent times is Virtual PC, originally produced by Connectix but then bought by Microsoft in early 2003. This move by the corporate giant reflects Microsoft's acceptance of the importance of virtualisation as a commercial solution for running applications on legacy Windows operating systems, allowing companies to continue to provide their users with access to their older systems while consolidating servers and making more efficient use of hardware. In this way legacy applications and operating systems can operate within a virtual environment created and maintained on a newer operating system that is more secure and stable. As a result many large vendors, IBM, HP, Intel and Dell included, make use of virtualisation (Lock, 2003), increasingly turning to products like VMware to run multiple operating systems with their own custom applications on the same set of hardware. As Josef Rehm of the large enterprise software company SAP states, VMware GSX Server "allows us to put our Windows NT® systems, which run on IBM eServer xSeries, together and operate them in a type of logical unit. As a result, we were able to spare ourselves the purchase of several servers" (IBM, 2004).

While initially at least Microsoft's interest in virtual environments was driven predominantly by its purely commercial uses, they quickly seized on the opportunity to exploit the power of virtualisation as a learning mechanism. In fact in a matter of months after the purchase of Virtual PC, Microsoft began releasing courses with ready-built, fully-configured virtual machines. For example, the Microsoft Official Curriculum course on Exchange Server 2003 (MOC 2400B) provides four virtual machines for each student. This adds credence to the statements of VMware management, who after the announcement of their partnership with Novell some years earlier, claimed virtualisation reduced the time required to set up classrooms, improved management and utilisation of hardware, and allowed students to experiment without risk of harming the operating system and applications (Shankland, 2001). This is due to the fact that virtual machines are simply stored as files on a physical machine, making them capable of being copied from one physical machine to another and still be able to work perfectly well, in this way breaking their dependence and connection to a particular set of hardware.

It is only possible to leverage VMware fully if virtual environments exist within the framework of a cohesive support infrastructure. This infrastructure at the Christchurch Polytechnic Institute of Technology (CPIT), which began in one specialist laboratory and has since the beginning of 2004 expanded to three, comprises of a Windows Server 2003 Active Directory domain, Group Policies, file servers for data storage, a client deployment solution, user account creation tools, the efficient use of switches, routers and cabling, Internet access for both physical machines and where necessary virtual machines as well, a booking system that allows students to reserve a particular machine in one of the specialist suites, and making course resources available on the Internet through a product called Blackboard. At the heart of this infrastructure, though, is the VMware GSX server (version 2.51). It hosts the tutors' virtual servers for each class and is easily accessed by students at any time of the day or night, so that in the event of students missing a class they can do the required laboratory work in their own time.

An added benefit of VMware is that it significantly reduces the need for handling media and hardware devices. At CPIT technical computing classes regularly make use of disc images in order to install operating systems and applications. It's not just that staff and students are saved the cumbersome task of removing CDs from sleeves and placing them in physical CD ROM drives but it also ensures faster access speeds, as ISO images are typically quicker to install from than from CDs, even when the ISO image is located on a server on the other side of a level-four switch. (In fact ISO images are useful for providing access to all kinds of data, not just installation files.) The advantage of faster access speeds are even more pronounced in the case of floppy disc images. In one course students are asked to create a bootable floppy that will lead to the appropriate %systemroot%\system32 folder on a Windows XP Professional machine. While this may be accomplished with a physical floppy, a virtualised floppy disc can be used just as easily by simply creating a file with an flp extension and mapping it to the floppy drive of the virtual machine. From that point on the file created is for all intents and purposes a physical floppy that has been placed in the floppy drive of a physical machine; it can be formatted and made bootable in the normal way. While actual physical floppy discs may also be used, many students prefer to use virtual ones instead because of the faster access speeds and sheer convenience.

3. LIMITATIONS OF VIRTUALISED ENVIRONMENTS

So what, one may ask, are the limitations of virtual environments? Guest operating systems, whether they are VMware, Virtual PC or some other variety, cannot do absolutely everything that a host operating system can do. It is often difficult, for example, to run virtual machines within virtual machines (Lorincz, Redwine, Sheh, 2003) and virtualised environments have problems dealing with non-standard size floppy discs. In the past VMware has also not coped well with power management options, such as standby and hibernation. These are, however, isolated examples. The truth is that what can't be done is negligible. More importantly, emulation offers students the freedom to experiment with a range of other technologies that would otherwise be simply too expensive or inconvenient to implement in the classroom. For example, it is easy to add discs to virtual machines (as these are simply additional files) and in this way configure RAID0, RAID1 and RAID5. Similarly if one wants to explore the intricacies of routing it is possible to add network interfaces to virtual machines, beyond even the usual limit of three interfaces allowed by the graphical user interface of VMware. In none of these situations is additional hardware resources required.

With the exception of tutors' virtual machines, all other virtual machines are stored on local student workstations in one of three specialist suites, so that a student has no choice but to sit at the same workstation in every class session for a particular course. After all, that is where all changes that student has made to his or her virtual machine is stored. The reason virtual machines are not stored in a central location (a server), so that students can access them from anywhere, is that virtual machines demand significant computing resources and the most any one VMware server can run concurrently is 20 virtual machines, not enough for one class, let alone six or seven. Copying images between a central server and student machines is also not practical as virtual machines are mostly large (at times over 2 GB) and this would generate significant network traffic as well as intense disc activity on the server. More importantly perhaps is the question of redundancy and fault tolerance. It is not possible at present to provide comprehensive backing up facilities for all students' virtual machines, because of the sheer volume of the data and limited resources. Fortunately it is not really necessary, as it is possible to restore a student's machine to a state where that student will lose very little work, even where a physical hard drive has failed. What is important is that the classroom server for each course is backed up, as this is not necessarily as easily restored to its previous state.

4. CONCLUSION

The separation of the virtual and the real is a basic principle of the learning environment at CPIT. In fact each physical machine has at least two network cards (they may have more), so that guest machines can be on an entirely different physical network to hosts. These networks are labelled the "blue" network ("blue" because it is secure and comprises of machines students cannot configure) and the "red" network ("red" because it is not a secure network as students have complete access to these machines). While it is possible to connect host and guest machines in the same network, retaining this dual topology helps protect the stable support infrastructure from the potential volatility of an experimental, learning environment that is virtualised, and has the added advantage of making more efficient use of network bandwidth, as traffic from host machines are not affected by traffic from guest machines. In a similar way each student machine has two physical hard drives, one for the host operating system (Windows XP Professional), linked to the blue network and the other to store VMware images and related data that form part of the red network and are secured by appropriate NTFS permissions. Not only does this keep the host and guest operating systems physically separate but it also enhances performance as the load is distributed between two physical discs. (We hope in future papers to document the network topology as well as the access rights and NTFS permissions implemented on the network.) This physical separation between the virtual and the real delineates the support infrastructure of a regular network that needs to be robust, secure and stable from the learning environment that should provide students with the freedom to experiment and learn.

In both the commercial and academic sectors virtualisation is an attractive option because it provides "secure, isolated sandboxes for running untrusted applications" (kernelthread, 2004). By having one application per server, something that is usually prohibitively expensive in all but virtual environments, failures of one application cannot affect the failures of other applications, and it is essentially this construct that shapes the use of VMware at CPIT. Isolating the operating systems and applications of each course from those of other courses and indeed the host physical machines ensures that the support infrastructure is robust and secure. Failures in virtual machines of one particular course do not affect those of other courses or (worse) the physical infrastructure as a whole. It is this element of isolation that is perfectly suited to learning, whether it be the mastery of existing technologies or research into the behaviours of particular software. Each virtual machine provides an added execution environment, without the cost of obtaining or maintaining additional hardware resources. It is this abstraction that promises everyone engaged in learning, staff and students alike, a range of practical experience in every way comparable to that of a 'real' environment. Perhaps just as compelling, this use of virtualisation exposes students to a technology that is finding increasing favour in the industry, one that prompted Andy Butler of the Gartner Group to comment that "Virtualisation is the single biggest thing that will happen to the server market over the coming two to five years" (Howorth, 2003).

REFERENCES

IBM (2004). "HARTMANN offers Health and Well-being with IBM and SAP: business solutions by IBM and SAP." Accessed 13 March 2004. http://www-306.ibm.com/software/success/cssdb.nsf/CS/MFRH-5LFJ7Y?OpenDocument&Site=software.

Nieh, J., Leonard, O. C. (2000). "Examining VMware." Dr Dobbs Journal, August 2000. Accessed 14 March 2003 <http://www.ddj.com/documents/s=882/ddj0008f/0008f.htm>

McEwan, W. (2002). "Virtual Machine Technologies and Their Application In The Delivery Of ICT." In Proc. 15th Annual Conference of the NACCQ, Hamilton, New Zealand. 55-62.

VMware Inc. (2001). "VMware Training for the Future: How VMware Workstation Delivers Tangible Value to the Training Business." White Paper. Accessed 14 March 2003 <http://www.VMware.com/pdf/VMware-training.pdf>

Tuip, M. (2003). "How to Build your own Windows 2003 cluster in VMware." Accessed 6 March 2004. http://www.exchange-mail.org/articles.html

Lorincz, K., Redwine, K., Sheh, A. 2003. "Stacking Virtual Machines – VMware and VirtualPC" www.eecs.harvard.edu/~konrad/References/ notes/CS253-VMware-Report.pdf. Accessed 6 March 2004.

Shankland, S. (2001). "Novell tows VMware into Education Market." Accessed 7 March 2004. http://news.com.com/2102-1001_3268219.html?tag=st_util_print.

Date Stockman, M. "Creating Remotely Accessible 'Virtual Networks' on a Single PC to Teach Computer Networking and Operating Systems Courses."

Lei, K., Rawles, P.T. (2003). "Strategic decisions on technology selections for facilitating a network/systems laboratory using real options & total cost of ownership theories." Conference On Information Technology Education archive: Proceedings of the 4th conference on information technology curriculum on Information technology education. ACM Press, New York.

Di Pietro, H. (2004). "VirtualPC 2004 vs. VMware 4 Performance Review." Accessed 12 March 2004. http://usuarios.lycos.es/hernandp/articles/vpcvs.html.

Vizard, M. (2004). "Virtual Computing." Accessed 8 March 2004. http://www.crn.com/sections/columnist/columnist.asp?rsid=crn&articleid=38403.

Goodwins, R. (2004). "Making Servers Virtually Better." Accessed 14 March 2004. http://insight.zdnet.co.uk/specials/upgrades/0,39021190,39116900,00.htm.

Lock, T. (2003). "VMware Boosts Intel Virtualisation Value." Accessed 19 March 2004. http://www.it-director.com/article.php?articleid=10998.

Kernelthread.com (2004). "An Introduction to Virtualization." Accessed 19 March 2004. http://www.kernelthread.com/publications/virtualization/

VMware (2004). "VMware Partners With Novell to Provide Innovative Training Solution." Accessed 27 March 2004. http://www.VMware.com/news/releases/novell.html.

Howorth, R. (2003). "Virtual servers set for takeoff." Accessed 5 April 2004. http://www.networkitweek.co.uk/News/1143721.

Rist, O. (2004). "Vexed by Virtualisation." Accessed 19 April 2004. http://www.infoworld.com/article/04/04/02/14enterwin_1.html.