Bringing Together a Low-Cost Networking Learning Environment

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ABSTRACT
There are many challenges typically encountered by a tertiary institution setting up applied networking resources. Such labs are necessary to create industry-ready graduates. Smaller institutes face particular issues where they lose the benefit of economies scale. This is because networking resources usually scale particularly well as the number of users increases. In an earlier paper [5], the author discusses how the skills and equipment necessary to run a Cisco Network Academy can be used to build an effective Faculty-wide network for teaching and research use, at minimal cost. This paper builds on the first with an emphasis on equipment and personnel experiences. The focus in this paper changes from a ‘Learning Network’ built on Cisco Network Academy experience, to a wider ‘Learning Environment’ that is far more than just a computer network.

This paper describes a range of elements of the Learning Environment. The political environment is described briefly, then put into context of an overall, ‘living’ environment of many different aspects, built over the years 2000 to 2011. Initially some relatively static elements of the environment are discussed, including an outline of the political and historical environment.

The way in which the School of Information Technology at Whitireia New Zealand adapted to that environment is considered with reference to the physical classroom environment over the years of this study. Technical elements are then described, particularly hardware and networking resources available. People skills are described next – the way the Learning Environment is used by academic staff, and the invaluable technicians employed over the years. There is consideration of a recent, and very exciting, addition to the Environment, then a look at the crystal ball of future directions, and mirror of lessons learned.

This paper will contain information useful to anyone managing an applied network lab, or a wider environment for teaching Information Technology (IT) courses.

Categories and Subject Descriptors

General Terms

Keywords
hardware, software, networking, low cost, small, research, teaching, VLAN, image, wireless, wifi, supercomputer, Weta, learning environment, VLSM, Cisco, Linux blades, VMware.

1. INTRODUCTION
How do we build a quality teaching network for a small organisation?

Computer networks scale well. Many functions required of a large network (with thousands of users) are fundamentally the same as a small network (perhaps two hundred users). This paper is a case study exploring how the School of Information Technology at Whitireia New Zealand has been able to build a quality and successful network environment for approximately 150 students and staff, without the benefits of scale enjoyed by a larger institution.

The network started with ‘end of life’ equipment from other parts of Whitireia. Gradually this was updated, and new equipment added. By the end of 2010, the Learning Environment was an established part of the institute, with quality equipment in all critical areas, and was able to integrate a significant donation of blade servers, and make these available for students.

2. EXTERNAL FACTORS AFFECTING THE SCHOOL OF IT ENVIRONMENT
The resources that can be offered to students are always going to be heavily influenced by factors outside the school in which the students are studying. This section briefly outlines the New Zealand education environment at the start of the 21st century and elements of the political and academic environment at Whitireia NZ.

Such an outline will add to the understanding of the technical developments over that time, which will be discussed in later sections.
2.1 New Zealand Tertiary Education

The New Zealand educational environment was transformed in the 1990s, particularly with the creation of the New Zealand National Qualifications Framework (NQF)\(^1\). This structure assigns 'levels' to education from 'year 11' (about 15 years of age) up. Three years of a typical Bachelor's degree are at levels 5, 6, and 7. Part of this process of 'equal treatment' of institutions was the provision for Institutes of Technology and Polytechnics (ITPs) to offer degree courses. While there are five different types of provider of tertiary education in New Zealand, Universities and ITPs provide the majority of level 6 and level 7 networking courses.

2.2 Local Control

Tertiary education providers in New Zealand have a large degree of autonomy over courses offered, and management of those courses. The government provides a significant proportion of income (49% for Whitireia Community Polytechnic in 2009 [17]), and access to that funding is subject to political changes.

In the context of this paper, the most important part of this autonomy was the ability of each ITP to determine the nature and content of the courses offered. Initially papers offered by ITPs, and subject to a national quality assurance process, centred on: use of applications; applications development; systems design; with some networking and operating systems papers [13]. That has steadily changed, as the global information technology environment has changed, during the 21st century.

2.3 Information Technology Courses Offered at Whitireia NZ

In 2000, Whitireia established a Cisco Network Academy, based at the new Trades campus being developed at the time, at Mohuia Crescent [16]. Initially, the Cisco Network Academy Program (CNAP) papers were used as part of a National Diploma [9], and also offered as a selection of standalone papers, for those wanting an industry certification [6].

Between 2005 and 2008 there were a number of political and academic changes that resulted in Whitireia redirecting all higher-level IT students into the Bachelor of Information Technology degree (BInfoTech). Students wanting additional preparation for the degree can enrol in a Certificate in Information Technology (CIT). Subsequently, all information technology courses have been offered by the School of IT.

2.4 Reliable Access for Non-Teaching Computing Needs

While the Learning Environment provides excellent resources for teaching, that environment is not intended to offer the reliability and security required for staff to manage other needs. Some IT resources are provided externally to the School of IT.

Staff and students using the Learning Network have always had access to the production network, and Whitireia productivity and administration systems. These systems provide secure, reliable services. Sensitive, confidential, or irreplaceable data is not held on the Learning Environment.

The term ‘Learning Environment’ is used to distinguish the services provided by the School of IT staff to support the learning of their students. This separation has resulted in the situation where the School of IT does not need to provide all the services expected of a production network. Storage, email, printing, and numerous other services are provided by the production network, and do not need to be duplicated in the same way in the Learning Environment.

3. PHYSICAL TEACHING ENVIRONMENT

After outlining the environmental background to the School of IT, this section describes the various buildings that have been used for teaching networking at Whitireia.

This section will consider also how the equipment used to support those devices has evolved over the years.

3.1 The First Network Resources

Applied, industry focused, and relevant, learning has always been a key objective at Whitireia NZ. In the mid-1990s, this was achieved using a minicomputer and set of terminals – surplus equipment donated by an industry partner. This is an example of how relationships with the IT industry have always been a key resource, for guidance to current practise, and a source of relevant equipment.

At that time, the Whitireia campus largely comprised prefabricated buildings (prefabs) – manufactured in another town – each 12 metres by 7 metres. Most of these buildings had an area about two metres long, and the width of the building, which we used for ‘servers’ (often also desktop PC class machines).

3.2 Dedicated Network Labs

At the Whitireia Trades Campus, in 2002, a new prefab, numbered MC105, was commissioned to house a course teaching applied PC support.

A new room layout was designed to suit applied hardware and networking papers, including extra cabling to enable the flexibility required to deliver networking courses. The layout chosen is shown in figure 1. This basic layout is still being used (at a different location).

Each of the 20 workstations in MC105 had four network connections. This flexibility continues to be a key asset, enabling students to reconfigure the environment to meet their needs. In 2003 a dedicated hardware lab was also created. Whitireia also offered courses at Paraparaumu, which is about 40 kilometres from Porirua. During the 2003 and 2004 academic years a network lab was used to offer the same papers as Porirua.

\(^1\) http://www.nzqa.govt.nz/about-us/our-role
3.3 Consolidation of IT Resources
With significant growth in the IT (particularly Networking) programmes, it was decided at the start of 2008 to move the Networking classroom to the central Porirua campus (Wi Neera Drive). This brought all resources for the BInfoTech degree to one site.

4. NETWORK & OPERATING SYSTEMS GROWTH
Previous sections have described external factors and physical environment of the School of IT. This section describes the evolution of server and networking technologies, which lead to provision of a Learning Environment for students and staff. That will prepare for sections describing where these subject areas are heading.

4.1 Early, Old, Equipment
Initially, the Mohuia Crescent server room (shown in figure 1) contained one server and a Linux router for internal traffic.

The server was an old Dell model, 'donated' by Whitireia production network support services (ICTS). It provided basic file services, while an old desktop PC was used as a router. Both machines were running Linux. A Cisco router provided a slow, but very reliable, and, by New Zealand standards, very low cost, Internet connection.

When the remote lab was commissioned in 2002, the labs were linked using a second Cisco router, and a VPN connection between the two, using two more previously de-commissioned servers, and a Novell Netware and eDirectory environment.

A range of desktop computers were also used for various, non-critical services.

4.2 Wireless Networks with Multiple Locations
Students studying the Whitireia Bachelor of Information Technology (BInfoTech) degree typically spend six months during their final year working on an Industry based "Capstone Project" [3]. For the 2004 academic year Capstone Project students were relocated to Mohuia Crescent. They were connected to the established Learning Environment with a wireless bridge, as it was not practical to take a cable to the building they used.

When the remote Lab was decommissioned in 2005, the Netware servers were replaced with Linux. In 2006 two new servers were purchased for the Mohuia Crescent lab. One ran Microsoft Windows 2000, used predominantly to distribute classroom images, using Symantec Ghost software. The other server used Linux, used primarily for file and print services.

Wireless networking became significant in 2005. Firstly, funding was provided to set up public wireless access in one building (‘E Block’) on the Wi Neera Drive campus, including provision of high-speed Internet access through the Wellington Internet Exchange [18], then Capstone Project students were moved to the Wi Neera Drive campus. The three sites then in use: (figure 2), could be linked by a wireless network, so equipment was purchased to put a long term link in place.

Routing between the three locations was implemented using a Linux routing solution.

4.3 Evolution to Current Technology in the Classroom
Use of virtualisation was a significant change in 2007. Instead of provisioning operating system classes using partition images stored on a local hard drive [4][3], VMware software was introduced, consistent with trends at the time. [8][14][15] Server virtualisation can also be combined with use of virtual local area networks (VLANs) for further flexibility [1].

4.4 Current Technology in the Server Room
Current technology in the classroom was still being supported by a mixture of ‘servers’ comprising ‘retired’ desktop machines and old server hardware. In 2009 an enterprise-scale server was purchased, and about the same time, the Faculty signed up for the "VMware ELMS Store", which gives access to most VMware products at no charge, for research and teaching use. VMware Virtual Machines rapidly replaced old hardware. Each physical server, running VMware ESX server, can host a number of virtual machines.

This has greatly simplified the management of the server environment. Guest servers, and workstations, can now be managed from software such as the VMware vCenter Server console. It is interesting to note that while the servers are old by industry standards, we have experienced a very good reliability record. At the time of writing (mid 2011), the enterprise server, purchased in 2009, is the only one under warranty cover. Three others were purchased, new between 2006 and 2008, and all appear to be working without any faults. Older servers are starting to be less reliable.

5. CONSOLIDATION AND RAPID EXPANSION
Previous sections have described each critical aspect of building and consolidation of an appropriate infrastructure for delivery of Information Technology courses. This section brings the reader up to the present situation before the final section discusses what the future might hold.
5.1 Free Public Wireless Provision

An entry into the provision of public wireless Internet was mentioned in section 4.2 above. That consisted of offering visitors the option of using a third-party commercial wireless network.

As part of a wireless networking paper, offered in July 2008, funding was obtained to buy equipment to support a trial of public, free, wireless Internet in E Block. Students researched and implemented the necessary steps for a trial network. In this way students achieved the necessary outcomes for their wireless networking paper, and Whitireia got a well-documented trial public wireless LAN at minimal cost.

The trial was a unqualified success. Security measures put in place were adequate to track usage. No undesirable activity has been detected or reported on either the trial network, or the fully operational version, which is described here.

In 2009, a Capstone Project was created to establish public wireless access in Te Kete Wānanga, the Whitireia Library building. This project included collaboration between the Business and Information Technology Faculty and Whitireia ICT Services (ICTS). ICTS provided hardware in the form of access points and switches, and left it to the BInfoTech project students to install and configure then. Again, this was a successful project: students got ‘A’ passes for their project; ICTS were able to complete their own wireless service; and the Faculty was able to finish provision of a public wireless network. All this was accomplished with a very low budget.

Whitireia ICT Services implemented a corporate wireless network during 2011. The popularity of the School of IT public wireless was recognized when it was still made accessible on the ICTS backbone over all of New Zealand, with slower connections to Australia and the United States. Connections are also provided to various Google and Microsoft services, with expansion plans.

Whitireia operates a campus in Auckland, about 900 kms from Porirua. Courses offered on this campus include the BInfoTech. It is planned to connect the Auckland School of IT students and staff to the Whitireia IT Learning Environment, using KAREN to link the two networks. Resources can be shared, and all students and staff will benefit from the enhanced environment.

5.2 Rapid Wired Growth

At the start of 2009, the Learning Environment supported a total of about 70 fixed machines and up to 25 wireless clients at one time. In February 2009, the production network was seriously impacted by the Conficker worm [19]. It was decided to change a classroom containing 30 computers from ICTS to the Learning Network, to relieve this impact on School of IT students. This added about 40% to the number of fixed computers, and roughly doubled network traffic. There has not been any sign of Conficker in the Learning Environment.

Continued rapid growth in numbers of IT students, and the success of the February 2009 expansion, resulted in further expansion in July. An additional classroom, also containing 30 computers, was added to the Learning Network. At this stage the infrastructure was upgraded, replacing an aging Linux PC with a Cisco gigabit layer-3 ‘core’ switch.

6. EXPANSION OF RESEARCH CAPABILITY

The 2009 expansion of desktop computers described in the previous section paved the way for improved quality and variety of services during 2010. There is no obvious need to make significant changes to the day to day running of the Environment in the foreseeable future.

There are other services that could be offered, which are described here.

This paper will then describe the way in which technical staff have been employed to support this environment.

6.1 IBM Blade Servers

Over the years, Weta Digital, in Wellington, New Zealand, have been credited as home to many of the most powerful supercomputers in the world2. In June 2005, Weta, had a supercomputer in the top 100. This resource has frequently been referenced in the technical, academic, and mainstream media [2][12]. The ‘top500’ references above show that Weta changed from an IBM BladeCenter HS20 platform to a Hewlett-Packard Cluster Platform 3000BL in 2007. Late in 2009, the last IBM equipment was donated to Whitireia [11].

This donation includes four data cabinets, populated with over 300 Xeon EM64T 3.6 GHz blade servers, each with 8 gigs of RAM. Plans are underway for long-term use of the bulk of this resource for supercomputer cluster applications. There is also a significant quantity of older blades. Two chassis of blades with older, 32-bit, 2.8 GHz Xeon processors, have been allocated for general Learning Environment use. In June 2011, the first Whitireia students were able to start using these blades for their course-work. The course chosen requires Windows 2008 implementation. Each student has been allocated one blade, running VMware ESX host software, all managed as a VMware vSphere cluster. It is used to provide services to students and staff, as well as being in use directly by students, as part of their learning.

There will be other uses for the blades. An example is the work of a Capstone Project team to provide a virtual reality simulation server. This provides a ‘Wonderland’ environment [7].

6.2 High Speed Communications

Early in 2011, the Learning Environment was enhanced by a connection to the Government sponsored Kiwi Advanced Research and Education Network (KAREN)3. Whitireia has a one gigabit connection to this network, which operates a 10 gigabit backbone over all of New Zealand, with slower connections to Australia and the United States. Connections are also provided to various Google and Microsoft services, with expansion plans.

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Connection to KAREN is also a key requirement to make full use of the blade servers. They are a resource much bigger than any demand from within Whitireia, however, connection to KAREN will enable them to be used by other academic and research organizations around New Zealand and worldwide. Those organizations could then contribute to the cost of running the blades as a supercomputer grid.

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1. 2 http://top500.org/site/history/2343
2. 3 http://www.karen.net.nz/about/
7. TECHNICIAN SUPPORT
Staffing an academic working lab is another challenge [10]. There are a variety of factors to consider, and ways to address the issue. This brief section outlines some of the factors.

7.1 Avoid Over-Commitment
It is important to acknowledge at the outset that the author believes, from personal experience and observation, that there is an imbalance in the support expectations of networking and operating system lecturers (infrastructure), when compared to application development lecturers. Both would like to always have equipment working to an agreed standard before class or lab work. The infrastructure lecturer will generally know how to fix many hardware and network problems. It is in the nature of teachers to want the best for our students from each session. The lecturer needs to draw a line, and remember that knowing how to fix a problem does not necessarily mean you should spend time fixing it.

7.2 A Computer is a Computer ...
There can also be pressure to use the same support services for an IT learning environment as is used by other disciplines. The most common rationale this author has heard is that there can be pure duplication – two people doing the same work, making the same mistakes, at the same time. Ten years of experience suggests this is not the case.

An example is the building of desktop images. Standard productivity applications tend to be used by all PC users, and can be installed by a mid-level support engineer. Application development images, however, can have far more complex interdependencies. The person building the image needs some knowledge of how do basic tests of each application, to ensure that each works when installed, and keeps working as other software is added.

Many support requirements are different. IT students tend to do their own first level support (usually successfully). They will then often log help requests online for anything more significant. When there is a need for support, it tends to be time-critical, such as a previously undiscovered software incompatibility.

The Whitireia Learning Environment does not significantly duplicate services provided by ICT Services (ICTS). None of the following services are guaranteed: file storage; email; printing; student results processing etc; wireless network; accounting; web services; remote access. Each of these services, if provided at all in the Learning Environment, is provided on a ‘best effort’ basis. It should be noted, however, that many of those services have been provided, on a very low budget, to the satisfaction of Whitireia students, for up to ten years.

Provision of an academic learning environment is best provided by academic staff. This is the same for Trades, Nursing, Education, Arts, and Information Technology.

7.3 Support Staff Over the Years
As one would expect, the increasing complexity of the environment has been accompanied by the engagement of increasingly skilled staff to support the networks. Two of the five technicians employed between 2000 and 2010 have moved on to work with ICTS. Each time there was talk of a ‘shared technician’ but this changed to a role with little time for the Learning Environment over a period of about a year. Interestingly, two IT hardware tutors are also now employed by ICTS. It should be noted that of the five technicians referred to above, two are still employed in the Learning Environment, so only one has left Whitireia!

Of the five technicians, all but one had first contact with Whitireia as students. Two staff members were employed in the Learning Environment from circumstances that made it difficult for them to find employment in industry. In these and other examples, the flexibility, exciting research opportunities, and relaxed environment have encouraged staff to stay in an academic environment when they could have got a higher remuneration elsewhere.

At the time of writing, technical and network administration support are provided by two staff on a part time, largely ‘ad-hoc’ basis in the Learning Environment. One of the strengths of the current networking team is that members generally work part-time (keeping down operating budget), but make themselves available in times of crises or heavy work loads (generally in student study breaks and at the beginning of each teaching semester). With future developments such as work with the blade servers and providing laptop support, it is anticipated that the hours of the support team will need to increase.

8. FUTURE DIRECTIONS
This paper has documented the path taken at Whitireia Community Polytechnic to build an effective, scalable, teaching and research network for Information Technology programmes.

All that remains is to consider the way forward, and summarize lessons learned from the past ten years. The lessons learned were described extensively in the author’s earlier paper [5] on this topic, and are summarized here.

8.1 Current Research – Future Implementation
Continued success running the Learning Network has improved confidence in our abilities. Firstly within Faculty management, and following from that, broader Whitireia management.

The current student use of VMware is providing scope for further research. There is potential to consider offering students a virtual ‘personal’ machine each. This is one of many options using grid computing, working with other academic partners.

8.2 Lessons Learned
There is an often-quoted metaphor of IT support being built out of three parts – quality, reliability, and low cost. The metaphor suggests that an increase in any one of these three factors requires a decrease in at least one of the others. The Whitireia Learning Network constantly manages this juggling act. Some of the ways this is done, and the implications observed, are listed here:

8.2.1 Beware of personal burnout
There are always enthusiastic students and staff, who “want to help”. Many stakeholders can see the benefits of growing the Learning Network, or adding new functionality. Sometimes we spend too many extra hours working on the network, and suffer some fatigue.

8.2.2 Communicate
Poor communication is blamed for the failure of many IT projects. Maintaining a network on a very limited budget does not leave space for waste of any resources through different participants not knowing what each other are doing. There are many areas where communication is essential. It is particularly important to manage user expectations and document everything!
8.2.3 Consider ‘Volunteers’ Carefully
Student, and non-technical staff volunteers are a high risk, requiring time to be trained, then find they don’t have the time they would devote to your project.

8.2.4 Watch Your Budgets and Time
Ensure classroom equipment is distinguished from infrastructure equipment. A careful balance needs to be found between the two. This is similar to the balance required between the teaching and research roles that academics must manage.

8.2.5 Use Low-End Equipment With Care, But Remain Open to Purchase of Second Hand Equipment
There is a reason why some ‘enterprise’ solutions cost many times as much as consumer equipment. Some Linksys devices (switches and access points) have been used, but is being replaced by various enterprise brands. Much of our Cisco equipment has been purchased from a New Zealand auction site. We have found all equipment purchased this way performed very well.

9. CONCLUSION
The Whitireia Community Polytechnic is a very small educational institute in world terms. We believe we have created an excellent, world-class, environment for learning applied application development and networking. We have done this by taking advantage of the skills of staff and students, and any other resources available to us.

This paper has described how we have used the skills of our staff and students to overcome the challenge of lack of size to build a quality teaching network for a small organisation.

10. REFERENCES