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DEVELOPMENT OF A VIRTUAL REALITY OVERLAY FOR VELNET (VIRTUAL ENVIRONMENT FOR LEARNING NETWORKING)

Ain Y. De Horta, Bruce Kneale and Ilona Box
School of Computing and Information Technology
University of Western Sydney, AUSTRALIA
{a.dehorta, b.kneale, i.box}@uws.edu.au

Abstract

The problems of providing a real, physical specialist laboratory to teach computer networking such as, the lack of funding and physical space and the risks and threats to the network environment and infrastructure, can be solved by the use of a virtual learning environment. Velnet is such a virtual learning environment that we have developed and used successfully. Velnet consists of one or more host machines and operating systems, commercial virtual machine software, virtual machines and their operating systems, a virtual network connecting the virtual machines, and remote desktop display software. In order to be able to present more computer-networking concepts and to improve on our original version of Velnet we have been developing a virtual reality overlay. This virtual reality overlay allows students to build virtual networking topologies in a virtual lab. This paper describes Velnet our virtual environment for learning networking and the virtual reality overlay currently under development.

Keywords

virtual learning environment, Velnet, computer networking

Introduction

It is widely recognised that learning about computer networking requires a 'hands on', authentic learning experience (AGILENT TECHNOLOGIES, 2001; Asia Computer Weekly, 1999; Costa, 2000; Kasim, 2002; Logical UK Ltd, 2002; Mateyaschuk, 1999; Montgomery, 2002; NORTEL NETWORKS, 2002; The Joint Task Force on Computing Curricula, IEEE Computer Society, & Association for Computing Machinery, 2001). However, being able to use an authentic learning environment to teach networking and incorporate practical, authentic, and valid assessment tasks can be problematic. The problems include: 1) lack of funds to establish and maintain networking hardware and software in sufficient quantity so that each student can have equal access to the learning environment inside and outside scheduled classes; 2) lack of physical space, both air-conditioned space for servers, and for the hardware used directly by the students; and 3) lack of a secure network environment that can reliably protect the other services provided on the same machines or network.

Some of these problems can be addressed by using a virtual environment. The use of simulations for teaching is not new. We consider some of the reasons why a virtual environment suits our needs based on propositions made by Winn and Jackson (1999). We then describe a virtual learning environment that we call Velnet (Virtual environment for learning networking). Velnet was developed and successfully piloted in 2003. We found Velnet can meet our needs by providing an authentic virtual learning environment. Velnet is now in hands by a virtual reality overlay. We describe this and the future development and research we will to with Velnet.

Simulations, Virtual Learning Environments, and Virtual Reality

Using a simulator to teach theory and practice is not a new concept. Research to substantiate the perceptions that simulators and the use of virtual reality are effective and beneficial is growing. Winn and Jackson (1999) presented 14 propositions about the use of virtual reality in learning environments. Of the 14 propositions, the six most applicable to our situation include:

- 1) Virtual environments (VE) are cheaper than a physical environment. The cost savings of using Velnet are presented elsewhere (Kneale & Box, 2003). Winn and Jackson go further by proposing that though a virtual environment may be less real, the trade-off with cost does not make the outcomes poorer. It may be that the student more easily transfers skills to the real world because the virtual environment is lower fidelity. A student learning in a high fidelity VE may expect that the real world will be the same and therefore be confused by small changes. Lower fidelity VE make the student generalise what they have learnt in the real world.
- 2) Virtual environments are safer. A VE provides a safe place to practice risky tasks. In our situation the safety of the network is one concern. Another is that the students feel safe to experiment without causing damage for which they may feel they would be reprimanded. This was also argued by Forbus *et al.* (1999)
- 3) Natural interaction with the VE allows students to experience metaphorical concepts and undetectable phenomena. Students can apply their networking skills and knowledge in a real environment by using a keyboard, a mouse, and a monitor. Velnet emulates this natural interaction. Taking this proposition further, an overlay of Velnet plus a VE helmet and glove would put the students in a VE where they could become part of the network from a bit on a bus, to a bridge, server or firewall; time can be slowed; concepts and non-detectable physical forms can take shape (Winn and Jackson refer to this as reification).
- 4) There is growing evidence that students, particularly those not academically inclined or committed, such as the majority of students undertaking higher education (Biggs, 1999), are more likely to do well and develop familiarity with the subject material in a VE. The students also then see the VE as valuable. Providing authentic learning experiences by modifying the laboratory environment may increase student engagement in the learning process and lead to high-order thinking in students (Cruikshank, 2002).
- 5) Constructivist concepts of learning and “first-hand” experience (Clancey, 1993) allows students to take what is familiar to them and add to this knowledge about networking that they gain by experiencing the VE. The VE can then be used to assess the student in an activity where the student given a problem to solve demonstrates their construction of meaning. Such an authentic assessment being judged on the student’s holistic performance of the tasks (Montgomery, 2002). This proposition is also lent weight by the advice from Braathen and Robles (2000).
- 6) The VE situates learning in a real context. The appearance of each virtual machine in Velnet is as it would appear as if a separate physical machine. Velnet has presence; the students can be convinced that they are working with a real network. They would directly connect their experience with Velnet to the real situation. Velnet is “real” enough for common networking tools such as protocol analysers and network management software to be employed to solve real problems. Students will encounter the same challenges using Velnet as in the real world: idiosyncratic operating systems, buggy implementations of network software, and difficult to understand user documentation.

Velnet (Virtual environment for learning networking)

Velnet uses existing hardware and software to present a virtual network environment in which students can securely and safely learn about and experiment with computer networking technologies.

The components of Velnet, shown in Figure 1, are: the host machine, a personal computer; the host machine’s operating system; VMWare™, proprietary virtual machine software; virtual machines and their operating systems; a virtual network connecting the virtual machines, and; remote desktop display software. Velnet appears as several windows on the host machine’s desktop, Figure 2.

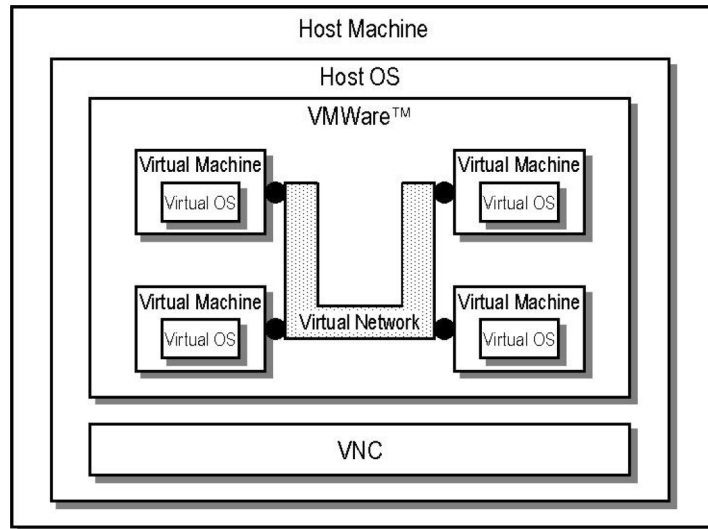


Figure 1. The components and configuration of Velnet

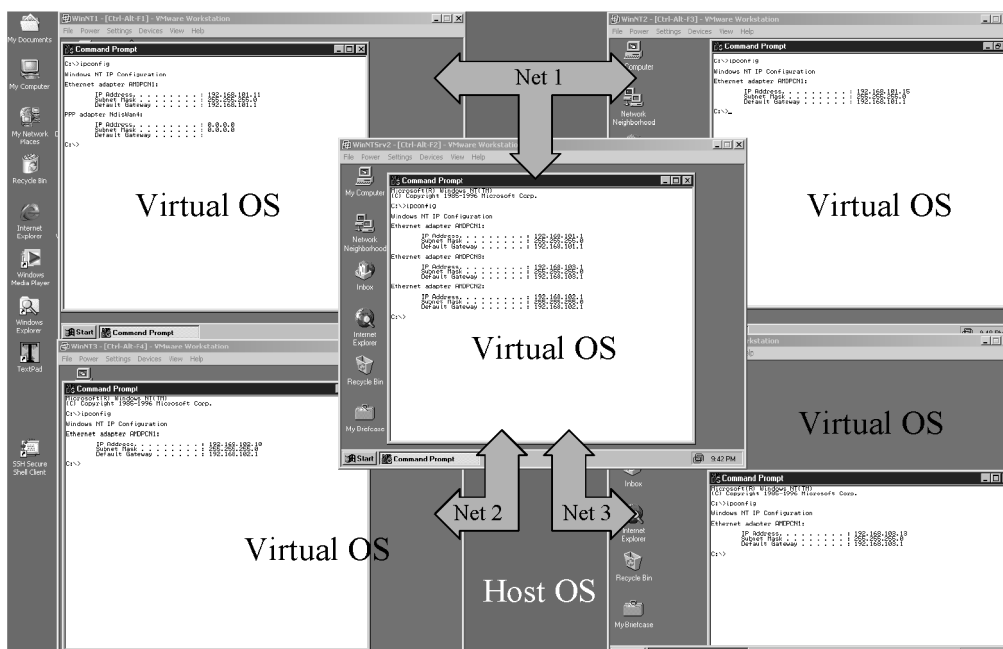


Figure 2. A Windows 2000 host with five virtual machines, each running Windows NT

Host Machine

Velnet is designed to operate on a single desktop host computer. As the host computer will be emulating several virtual machines the number of virtual machines that can “exist” simultaneously on the host computer depends on the amount of memory and CPU speed. The hardware specification used for our initial development of Velnet was: CPU, AMD Athlon™ 1800+; 1GB of memory (RAM); 60GB hard disk, and; an Intel® Pro 100+ network interface card.

Our first experiment with Velnet had one host computer running Windows® 2000 with five virtual machines. Four of the virtual machines ran Windows® NT 4 Workstation and the fifth virtual machine ran Windows NT® 4 Server that acted as a routing device for the other virtual machines. The Velnet pilot used six host machines running Windows® XP, each with three virtual machines. One virtual machine ran OpenBSD while the other two virtual machines ran Windows® NT Workstation. Windows® XP remote desktop tools were used to provide students with remote connectivity.

Host Operating System (Host OS)

Windows® 2000 was initially chosen as the operating system for the host computer for its ease of configuration and student familiarity with the system. Minor difficulties were encountered when using VMWare™ and VNC, as the remote desktop display software, as the two applications contended for mouse pointer control as the two virtual machines were running GUI based operating systems. The problem was not apparent for virtual machines running text based operating systems such as OpenBSD.

VMWare™

Velnet requires software that provides multiple virtual hardware environments on the one host computer. Several available applications were evaluated (Kneale & Box, 2003), the most suitable for our needs was VMWare™ (VMWare™ Workstation, 2002).

Virtual Environment

Virtual Machine

The virtual machine emulates an Intel® x86 hardware environment. From the time of “switching on” the virtual machine’s console appears and behaves as if it were a real, physical computer.

Virtual Operating System (Virtual OS)

The choice of operating system depends on desired learning outcomes, cost, and memory available in the host machine. Even though there is one host machine, each virtual machine has a separate identity and as such, appropriate licensing must be obtained for any operating systems used.

The choice of virtual machines for the initial standalone experiment was Windows® NT Workstation and Windows® NT Server. The choice of virtual machines for the pilot was OpenBSD and Windows® NT Workstation.

Judicious use of open source operating systems such as Linux® and OpenBSD provides less expensive alternatives.

Virtual Network

The virtual network runs in VMWare™, as a function of this application. Some of the components of a physical network such as switches and network adapters are emulated in the virtual network. Routing is supported by operating systems, which have this function and are installed on the virtual machines.

Velnet Virtual Reality Overlay

In order to further enhance the functionality of Velnet we are developing a virtual reality overlay. This overlay is designed to help students to learn more about networking by allowing them to construct and experiment with different networking architectures in a virtual lab environment.

Components of the Velnet Virtual Reality Overlay

The virtual reality overlay is shown in Figure 3. It has two main components: 1) on the left a Virtual Lab Area where networking components can be placed, interconnected, and configured to form a networking architecture; and 2) on the right Component Libraries containing various types of networking and networking related components.

Figure 4 shows all the current component libraries and components. We envisage that the number of components and/or libraries will be expanded and customised in future versions.

Using the Velnet Virtual Reality Overlay

To construct a networking architecture in the virtual lab takes much the same steps as is in the real world. A student would first select the components needed from the libraries on the right (Figure 3), just as they would select components from the shelves of a storeroom; then move the components to where they are needed, by dragging and dropping them in the virtual lab area on the left (Figure 3), by carrying them to

offices or rooms in reality; connecting components, again by dragging and dropping in the virtual lab, by cabling and interface cards in reality; configuring the devices forming the networking architecture, while at one machine in virtuality, at separate machines in reality, and; then testing the network, again while at one machine in virtuality, at separate machines in reality.

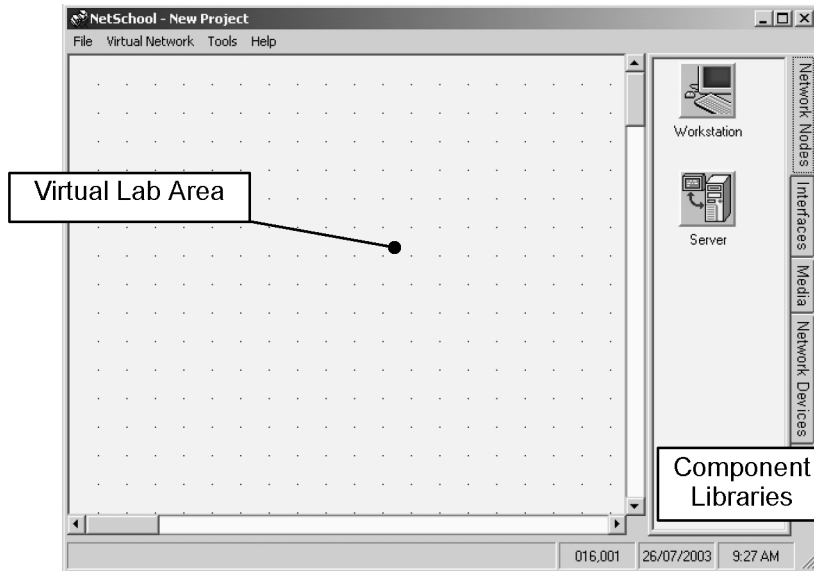


Figure 3. Velnet Virtual Reality Overlay

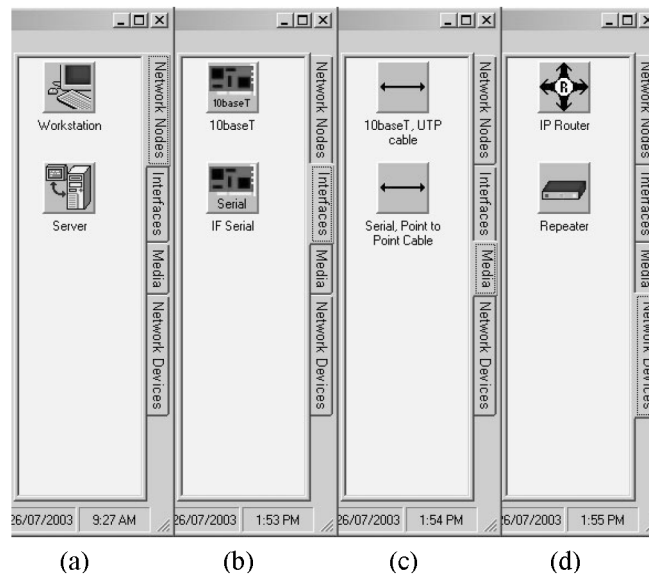


Figure 4. Component Libraries: (a) Network Nodes; (b) Interfaces; (c) Media; (d) Network Devices.

Constructing a Networking Architecture in the Virtual Lab

Consider, as an example, the network architecture shown in Figure 5. Typically, this exercise might be given to students as an elementary exercise in a networking subject.

Constructing the architecture shown in Figure 5 is simply accomplished. First, one selects a workstation from the library and places it in the virtual lab area. In order to connect the workstation to a network it will need a network interface card, just as in the real world. To install a network interface card one is selected from the library and installed in the workstation simply by dragging and dropping it over the workstation, mimicking the procedure in the real world. The procedure for the second workstation is the same as for the first workstation. The procedure for the rest of the architecture is even simpler in that we do not require the installation of network interface cards. Once the required routers and repeaters are

placed in the virtual lab area they will need to be interconnected by media thus complete the network architecture shown in Figure 5 in the virtual lab, as shown in Figure 6.

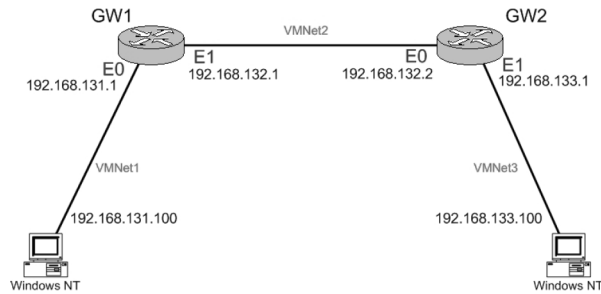


Figure 5. Typical teaching network architecture.

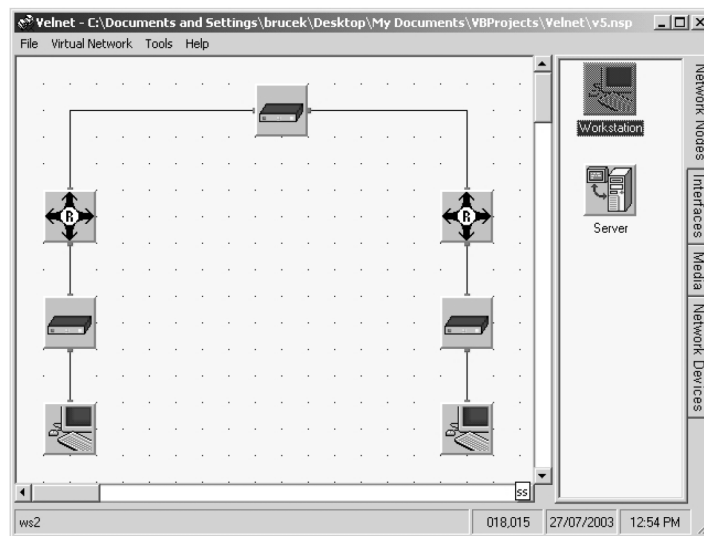


Figure 6. The network architecture shown in Figure 5 constructed in Velnet.

As in the real world, once the networking media to form the required network architecture interconnects all of the components of the network, it is then necessary to configure the relevant components such as routers, servers, and workstations. In the example, shown in Figures 5 and 6, the components that require configuring are the routers and workstations.

Configuring a Router

In the real world to configure a router requires us to first power up the router. In the virtual lab this is also our first step. This process is shown in Figure 7. The router is selected and powered up by selecting “Start Virtual Machine” in the popup menu.

This starts the virtual router, which in this case is a virtual machine running OpenBSD setup to be a router. The teacher would have installed the operating system on the virtual machine, using VMWare, so that it was available for the student.

Once the router is powered up we can open a console and perform the required configuration. Once again this is done by selecting the router and then selecting from the popup menu “Console” as shown in Figure 8.

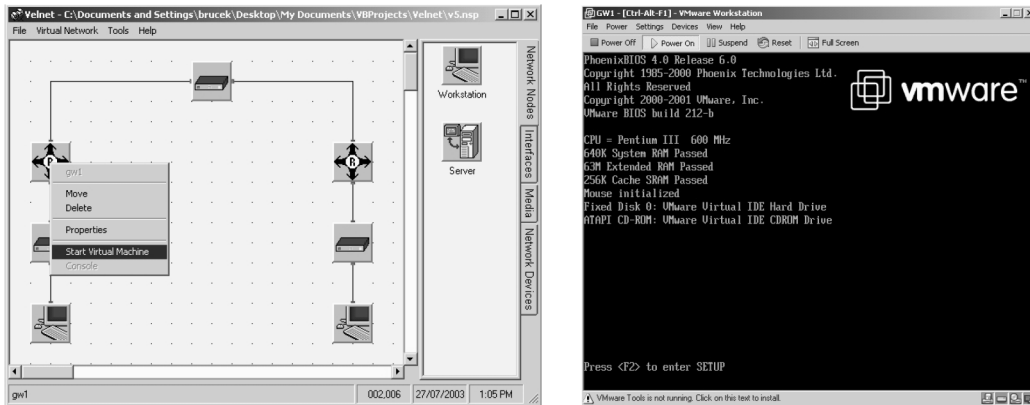


Figure 7. Powering up the router.

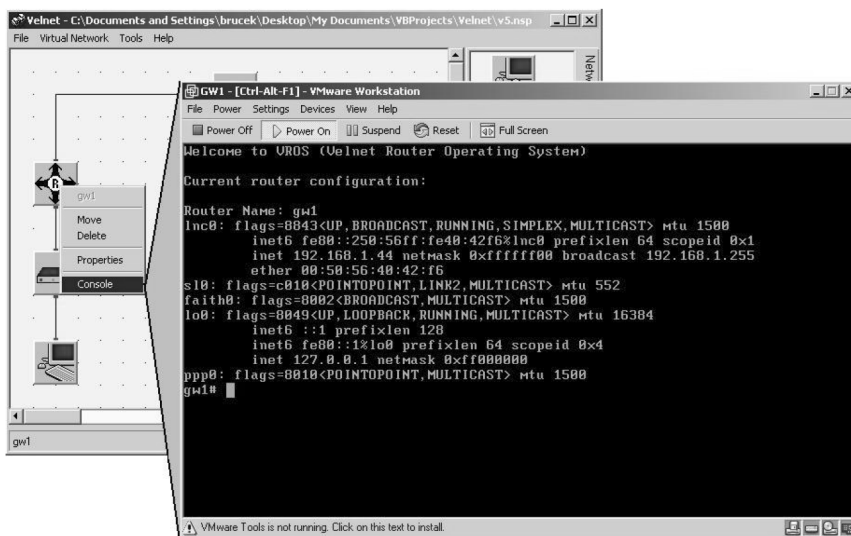


Figure 8. Opening a router console.

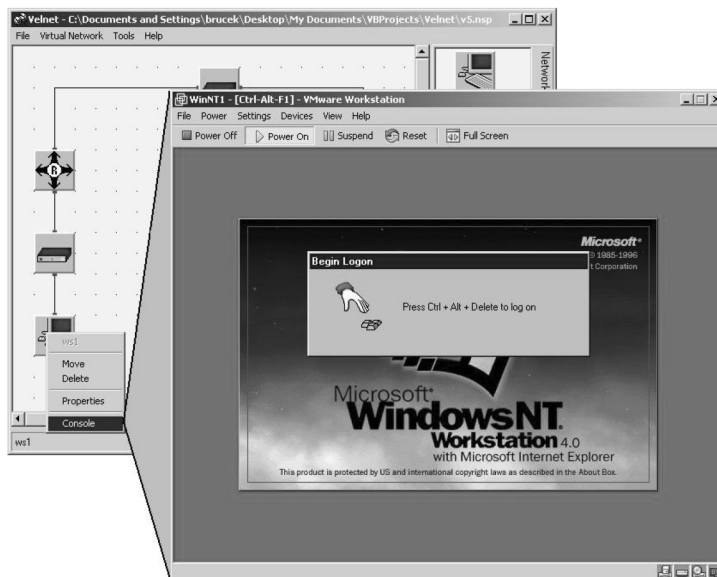


Figure 9. Opening a workstation console.

Configuring a Workstation

The process of powering up, or turning on, and configuring a workstation is identical to that for a router, except that when we open a console we are now opening a virtual machine running Windows NT 4 (WS) as seen in Figure 9. Again, the teacher made the virtual machine available to the student using VMWare.

We now have a fully functioning virtual network that can be tested and used to explore networking and networking related issues.

Future Enhancements and Further Research

Future Enhancements

The virtual reality overlay, as shown in Figures 3 to 9, runs as an addition to the first incarnation of Velnet. Therefore, some of the limitations of the first incarnation of Velnet, such as, one host machine per student (Kneale & Box, 2003) remain as limitations to the virtual reality overlay. Leaving Velnet as it is at this stage would mean that each workstation we would want students to use for practicals would need additional memory, processing power, and disk space. If we were to make Velnet available to students outside of their practical classes they would need to add additional memory, processing power, and disk space to their own computers and we would need to package Velnet, including VMWare, so they could install it. Providing Velnet at this stage of development still involves considerable cost.

We can reduce the cost to the student. Most tertiary educational institutions have general purpose computer laboratories that are accessible to students 24 hours a day 7 days a week, therefore a medium-term goal for the Velnet project is to provide access to Velnet via these laboratories using the institutions intranet. We are investigating a possible way of doing this via remote display software. This will allow students to interact with the virtual network from anywhere on the intranet. A typical Velnet scenario might be as shown in Figure 10.

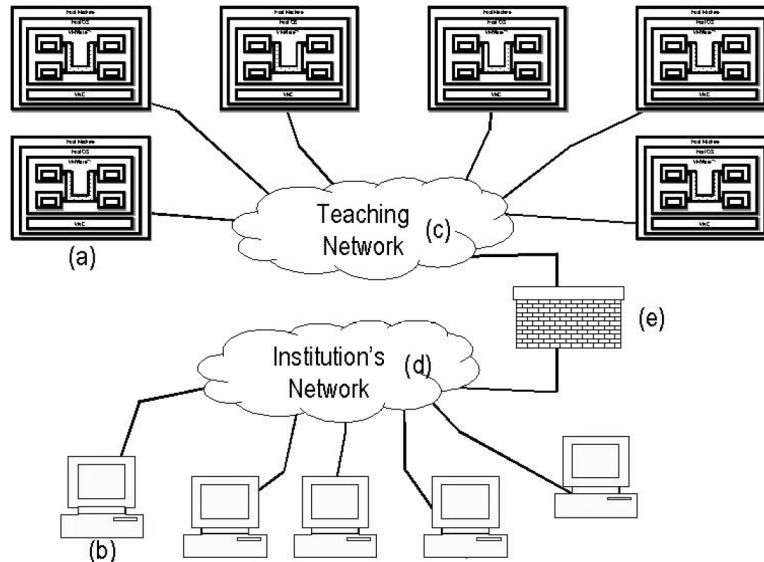


Figure 10. Typical remote access session to Velnet.

In Figure 10, Velnet is running as six host machines, each representing an individual network (a) and students gain remote access via any computer (b) connected to the institution's network (d). A network firewall (e) is used both to protect the broader network community from accidental or malicious actions within the virtual network and to restrict access to the virtual network to only those students enrolled in the subject. The firewall is configured to only allow remote desktop display sessions. Any configuration problems either with the virtual network or the host computer will be confined to the teaching network (c).

The remote desktop display configuration of Velnet still leaves the institution with the cost of providing multiple host machines. Another project under way is the development of a client/server architecture for Velnet. The client/server architecture will allow students to download a client application and connect securely to a server application. The client can be run on any machine with the capacity. The client looks like the virtual reality overlay presented in this paper. The server will be a very large host machine. The server looks like the original incarnation of Velnet. This project enhances Velnet and saves costs for the student and for the institution.

The aim of the Velnet project is to provide 24 hours a day, seven days a week access to a virtual environment for learning networking via the Internet. There are arguments for and against providing 24 hours a day/seven days per week access (O'Donoghue, Singh, & Dorward, 2001; Piccoli, Rami, & Blake, 2001). However, with careful instructional and assessment design the benefits expected and, arguably, the inevitability of the role the Internet will play in course delivery, make this aim reasonable.

In the longer term, we are considering the investigation and development of converting Velnet into an articulate virtual laboratory (AVL) (Forbus et al., 1999). An AVL, according to Forbus *et al.* would address problems of marking, timely feedback, coaching, and guidance.

Further Research

The technical issues of developing Velnet are one aspect of the research required to develop a virtual environment for learning networking. Other aspects are:

- The educational uses to which Velnet can be put,
 - the teaching of other topics, such as:
 - Distributed computing
 - Client/server application development
 - Advanced networking
 - Web engineering
- The evaluation of the use of Velnet from a pedagogical perspective, such as
 - By taking a constructivist approach to teaching computer networking the evaluation of the learning outcomes, experiences, and processes,
 - The benefits of providing first-hand experience,
 - Improvements or deficiencies in providing for those students not academically inclined or committed,
 - The learning outcomes, experiences, and processes of situating learning in a real context.
- The application of education research, particularly IT education research, to the learning and teaching of networking (and other topics) using Velnet.

Ultimately, the research that should be continued regarding the development and educational use of Velnet should show the worth of overcoming the problems of funding, space, security, and versatility to provide a practical, authentic, and valid learning environment.

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