

Remote Laboratory Access and Network simulation Tools for Students with Vision Impairment

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Abstract—The delivery of laboratory exercises to students that are unable to attend in person due to physical disabilities is a significant issue. Both Netlab and Packet Tracer are inaccessible to many students who use assistive technology, particularly those with vision impairment. This paper presents the development of an accessible, cost effective, remote laboratory and describes the modification to laboratory sessions necessary for the blind to undertake Cisco Certified Network Associate (CCNA) laboratory sessions remotely and with full accessibility. Also discussed is the development of an accessible network simulator, iNetSim, illustrating possible methodologies that may be applied to make existing simulation packages accessible to those with severe vision impairment.[1]

Keywords-component; Networking laboratories, vision impaired, accessible eLearning

I. INTRODUCTION

The image of a vision impaired person holding a job on an IT Help Desk or in computer network administration seems a bit far-fetched: computers are vision driven and the vision impaired person would have difficulty seeing the user's screen to diagnose and fix any problem. Quite to the contrary, vision impaired people are ideal for this job role. Whilst computers have cables, plugs and plenty of ports, once they are installed computer networks need little physical attention. The attention they do require is of a logical nature, establishing and maintaining connections and access to the data required by the users. Users on business networks constantly need assistance from computer network professionals and this usually takes place via the IT Help Desk. Vision impaired people may have mobility problems and require extensive orientation and mobility training for each locale that they are required to work in. However technical support jobs require logical knowledge and skills, not physical mobility, making IT Help Desk positions ideal for vision impaired people. Research undertaken by Curtin University in conjunction with the Association for the Blind in Western Australia has shown that accessible e-learning

environments can be developed to aid vision impaired adults achieve industry standard qualifications in IT networking. As computers become more ensconced in our private and business lives the need for useful IT knowledge rises. Industry standard training provides skills and knowledge for the vision impaired to maintain any computer network – their networks at the office as well as their home networks.

This paper describes an accessible e-learning environment designed to deliver advanced IT skills remotely, to legally blind students. The aim was to convert industry standard training written for the sighted into accessible formats for the vision impaired and deliver the learning materials in ways more suited to adult students with vision disabilities. The components of the learning environment, with particular emphasis on remote laboratory access, network topology graphics and simulators, are discussed together with the successes and problems faced in the hope that others may learn from our experience.

II. SCOPING THE PROBLEM

Vision impaired (VI) adults continue to face problems in gaining employment. In the US the 2006 Disability Status Report (www.disabilitystatistics.org) reported an employment rate of only 47.5% for people with any sensory disability [2]. The 2002 Household Economic Studies reported a 55.3% employment rate for persons with communications disabilities, including vision impairment [3]. A further study on vision impaired youth employment levels reported a 28% employment rate for out-of-school youth [4,5] reports 25% of vision impaired in the UK are in employment and “younger people tend to be better qualified and there is a high correlation between qualification level and employment”. Unemployment rate for vision impaired people in European countries in 2000 remained around 75% [6].

In each of these studies the employment figures for those with a vision disability were consistently lower than those

for sighted individuals. Major contributors to this situation are suggested to be inability to access further education and the digital divide created by the emergence of computers [7,8]. This raises the question 'Can vision impaired adult learners gain equivalent grades to sighted learners if specialist education was accessible'? If so, such training would increase their employability, giving opportunities for financial independence and a more 'normal' lifestyle.

A study of factors relating to employment of vision impaired in Turkey reports that education, gender, age, marital status and Braille literacy were significant factors that predict the probability that a vision impaired individual would be employed [9]. The low rate of unemployment in the vision impaired population has been the focus of much research and the main barriers to employment are reported to be the lack of employment skills, transportation, housing and access to information [10,11,12,13]. Although education and training is not the sole answer to the problem, post-secondary education and training has also been found to be a significant factor for obtaining employment in numerous other studies across the globe [14,15].

Capella-McDonnall's [16] study of factors relating to the VI gaining competitive employment reports four significant factors; vocational education as a rehabilitation service resulting in an educational certificate or degree, having worked since the onset of the impairment, reason for applying for vocational rehabilitation related to obtaining a job and a high quality relationship between the counselor and the VI client. Capella-McDonnall [16], p312) states "the effect of completing an educational program is powerful because the odds of attaining competitive employment were more than nine times greater for those who obtained an educational certificate or degree compared to those who did not receive education as a service at all."

Access to higher education and training in specialized skills in preparation for employment is also restricted to those who suffer from vision disabilities. The situation faced by vision impaired students attempting to gain contemporary advanced IT training and education was investigated by the authors. Although attempts have been made to increase accessibility of their training materials the major providers such as Cisco, Microsoft, Oracle, etc. still fall short in providing a fully accessible on-line environment for the vision impaired. Our analyses resulted in the following list of problems:

- Lack of student mobility to attend classrooms and navigate around a large university campus.
- Location in remote areas where education and training services are not available
- Inability to see the whiteboard in classrooms, necessitating the lecturer to explain in narrative form the concepts being illustrated
- Sighted lecturers unaware of the needs of vision

impaired students

- The inaccessibility of graphic and visual teaching and learning materials and limited access to textual materials
- Inability to access laboratory exercises and inability to carry out tasks without the assistance of a sighted person
- Inability to access written examination questions and answer in the traditional manner
- Inability to access interactive media, drag and drop, and similar electronic teaching tools
- Inability to access simulation software and common operating system such as Linux.

This posed a challenge, as several vision impaired students at Curtin University of Technology were studying Cisco technologies in their undergraduate degrees, and these problems were major hurdles to their completion of their courses of study. This project examined accessible alternatives to address each of these difficulties.

III. REMOTE LABORATORIES IN EDUCATION

The past decade has shown an increase in the uptake of remote laboratories for the delivery of practical exercises and distance learning in electrical engineering and computer-based education. The discussion as to the viability and effectiveness of real laboratories, virtual laboratories and remote laboratories is active with no resolution reached thus far. Gustavsson [17] claims there is nothing that will replace synchronous learning through face-to-face interaction. This is a brave claim as it assumes a homogenous student group. Enthusiasts of hands-on learning propose that working with real equipment results in much more information and many more cues [18], however the difference between preference and effectiveness needs to be considered. The study by Corter and colleagues [18] comparing remote and hands-on laboratories reported more than 90% of the student respondents rated the remote labs to be comparable or better than the hands-on labs. Ma and Nickerson [19] argue that although automated (simulated and remote) laboratories allow professors to teach large student numbers, automation may remove the serendipity associated with traditional laboratory learning. The flexibility of remote laboratories enables students to utilise the laboratory in different locations and at numerous points in times [20], as well as those with special needs [21]. A comparison of remote, real and virtual laboratories by Nedic, Machotka and Nafalski [22] found that remote labs also offer students a tele-presence in the laboratory, the performance of experiments on real equipment, collaboration, learning by trial and error plus the opportunity to perform analysis on real experimental data.

The main characteristic of remote laboratories when

compared to hands-on (also referred to as 'real'), simulations and virtual laboratories, is that students obtain the data and learning experience by controlling environments separated by geographical distance. The majority of these environments are offered via the Internet for easy access by students. The perception of reality by the student is at the core [23,24] and the aim is to immerse the students into the learning experience so that no difference from physical presence is perceived. Colwell and Colleagues [21] argue that practical work is imperative for learners of science to develop both their conceptual and procedural understanding.

Vision impaired students use screen reading software to convert the text displayed on the screen into audio output, or screen magnification software. This use of assistive technologies necessitates a different design of educational materials for the vision impaired, and especially laboratory exercises to concrete the learning by experience.

However, the design and development of laboratory exercises in distance learning for vision impaired students using assistive technologies requires a careful consideration of accessibility issues. Accessible materials and environments require careful planning and deployment of navigation mechanisms, structure, content design and communication methods, and the approach needs to be highly learner- centered [25]. A key factor in the design of learning environments is that the environment should not be the cause of any unnecessary frustration to the student, and should include the facilities to permit easier interpretation of the material, and also support direct interaction enabling students to spend their full cognitive resources on the task rather than the interface [26].

The use of remote laboratories has contributed to the offering of advanced transgeographic education being an affective means of eradicating ethnocentrism, xenophobia and cultural divides [27]. The divides caused by disabilities could also be added to that list, provided the remote learning environments incorporate essential accessibility features. With the majority of on-line learning materials in the science and technologies incorporating a vast amount of vision driven features, barriers to learning are erected for vision impaired students. These are characterized by a predominance of graphics, images and animation in the presentation of learning materials. The presentation of e-learning materials ranges from highly textual with accompanying images through to computerized exercises and games incorporating a high concentration of visual features to assist comprehension. All these components provide accessibility problems for vision impaired students. A diagram or picture clearly illustrates the concepts being introduced to sighted students, however, rarely are there detailed explanations of the diagram or picture in the supporting text. Blind students cannot see these diagrams

and students with acute vision disabilities also have great difficulty comprehending what is being taught. The inaccessibility of learning materials is highly evident in not only higher education environments, but also in on-line industry standard training courses.

IV. CISCO ACADEMY FOR THE VISION IMPAIRED (CAVI)

Curtin University of Technology commenced offering the Cisco Network Academy Program to mainstream (sighted) students as part of the Bachelor of Technology (Computer Systems & Networking) degree program in 2002. Shortly after, four vision impaired students expressed an interest in entering the Bachelor of Technology program. These students faced significant problems with accessibility to the Cisco course on-line materials as much of these materials were not accessible to non-sighted users. Extending the Cisco courses to vision impaired students posed numerous teaching and learning challenges.

The Cisco Academy for the Vision Impaired (CAVI) has been delivering the Cisco Academy Programs to blind and vision impaired students since 2003, with up to 9 students per year from the local area. In 2007 the program was expanded to include students located in other parts of Australia and the U.S.A, with 25 vision impaired students enrolled in that year. In 2008 the enrolments of legally blind students exceeded 120, from countries including India, Sri Lanka, Canada, Egypt, Australia and the U.S.A. During the intervening period, a number of vision impaired students entered the Bachelor of Technology (Computer Systems & Networking) course at Curtin University with the total number of vision impaired students (in the CAVI program) increasing to 146 in the year 2008. In order to achieve the practical components of the CCNA courses, remote access to router and switch bundles was required. A description of the remote laboratory established for these students together with teaching tools developed and an accessible network simulation application follows.

A. *The Mechanics of Delivering the Curricula*

The Cisco curriculum is "media rich", with much of the content delivered as Flash and interactive web pages. This style of delivery is often unsuitable for vision impaired persons. The arrangement of frames is inaccessible to screen review applications (speech output), but more importantly the curriculum relies heavily on visual keys to illustrate learning objectives. Several problems, not apparent to most sighted users, are also inherent in the curriculum design. The first problem is that the diagrams are extremely difficult to access or even explain to a person who has been blind since birth. The second problem is that the arrangement of frames and the lack of correct ALT labels (text equivalent buttons) add to the complexity of the presented material. The vision impaired students also advise they have no way of accessing the content of

interactive sessions and find the supporting text confusing and misleading. To overcome these issues many supporting applications and documents were created but are beyond the scope of this document.

The CAVI program utilizes blind instructors to deliver the Cisco course materials with the support of a sighted teaching assistant. Blind instructors have first hand experience of the difficulties encountered by the vision impaired students and understand the most effective ways of presenting the materials. The classroom environment consists of a laboratory containing a network of PCs fitted with assistive technologies, routers and associated network equipment. Classes run two full days per week over the academic year. Local students physically attend classes and remote students log in (via the Internet) to a virtual classroom to listen to the lectures and participate in the tutorial exercises. The virtual classroom provides the facilities for students to talk to one another as well as communicate with the instructors, similar to a normal classroom environment. The lectures are recorded and made available as audio files on the project website along with other teaching materials for access by the students at any time.

It may be argued that the most difficult issue in delivering e-learning to blind students is that of explaining the meaning of graphical information. To overcome this issue, textual descriptions were created for all graphics used in the courses, including the curriculum, laboratory manuals and on-line exams. An example textual description is given in the excerpt below and refers to the diagram in Figure 1, graphic 2 of 4 in the text description.

Page has 4 graphics

Graphic 1 shows the segmentation with routers. There are four hubs and one router in the picture. Router is in the middle connected to hubs in four corners, three stations (PC) are connected to each hub.

Segmentation with routers provides:

More manageable, greater functionality, multiple activate paths

Smaller broadcast domain

Operates at layer 3

Graphic 2 show routers connected by WAN technologies. There are 10 routers in the graphic. Four of them are connected to each other in a square shape (each one corner of a square). If we name these routers from 1 to 4 clockwise starting from the left top, router number 1 is connected to router number 2 with ATM (Asynchronous Transfer Mode). Router number 2 is connected to router number 3 with T1/E1 and T3/E3. Router number 3 is connected to router number 4 with ATM. Router number 4 is connected to router number 1 with T1/E1 and T3/E3. Each of these four routers are connected to other routers.

Router number 1 is connected to two other networks one a cable modem via a router and other one X.25 via other router.

Router number 2 is connected to a dial-up modem via a router.

Router number 3 is connected to SDMS via a router and to xDSL via another router.

Router number 4 is connected to ISDN network via a router.

There are antenna signal to router number 3 and satellite signal to ISDN router connected to router number 4.

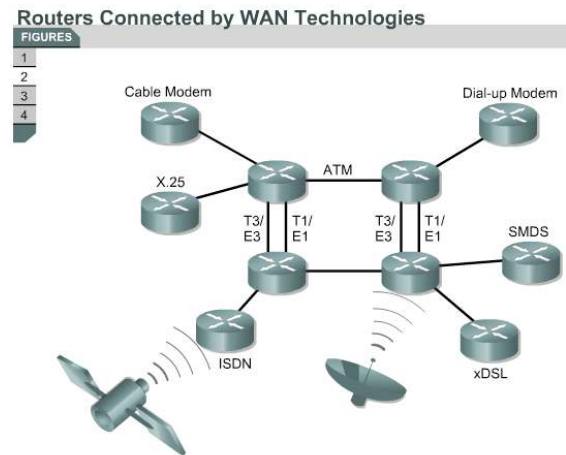


Figure 1: Example diagram from CCNA2 version 3.1 section 1.1.3

Further details of the teaching aids used in the project can be found in Murray [28] and on the project website <http://www.cucacat.org>.

V. THE REMOTE LABORATORY USER EXPERIENCE

Laboratory exercises form a significant portion of the curriculum. In order for students situated remotely to access and participate in the laboratory sessions, a functional, remotely accessible network topology was developed. The configuration illustrated was developed for the CCNA version 3.1 curriculum, with work currently underway to reconfigure for Discovery and Exploration curricula to be delivered in 2009. Laboratory equipment generally consists of three routers and two switches. The configuration may be described as two branch offices, say Perth and Sydney, connected together via the ISP or Internet cloud. The edge routers are configured by the students to allow connectivity via the middle router (cloud or ISP). Local students interact directly with the routers' configuration via serial (console) interfaces. A problem exists when attempting to allow remote students access to "real" routing hardware. The routers may not be placed on production networks for obvious reasons and initial configurations must be entered via the console connection. Therefore requirements for a remote lab must allow students to perform:

- Initial configuration via the console cable
- Remote power cycling of network equipment and workstations
- Connectivity tests
- Advanced router and switch configuration.

One such system does exist, Netlab, developed and distributed by NDG (<http://www.netdevgroup.com/>), however the cost of this system is a major factor hindering its adoption. Additionally, the java based applications in Netlab, including the booking system, telnet client to interact with the network hardware and server system are not accessible by screen readers (software utilized by blind computer users to convert on-screen information to audio or Braille output). The CAVI system developed costs significantly less than the Academy Edition of Netlab. Whilst it does not offer advanced features such as equipment booking it performs all the required functions for the vision impaired class applications. In its most simple form, it consists of the standard CCNA laboratory bundle: 3 routers and 2 switches, with several virtualized Linux PC servers running FTP, HTTP, Telnet and other associated services; all may be accessed by their serial ports (see Figure 2).

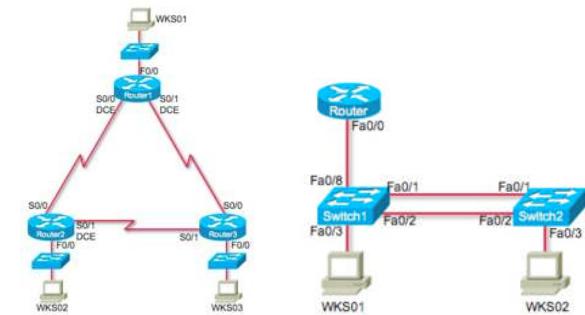


Figure 2: Standard router bundle (top) & Switch Bundle (bottom)

A standard serial port or console switch is used to access the devices in the laboratory bundle. Remote students may telnet into the console server (a device that allows Ethernet to multiple serial port connections), accessing the routers, switches and Linux servers from any locality worldwide. The use of Linux on the host and server machines is necessary as the command line may be accessed through the serial ports allowing the students to connect directly to the server hosting the multiple virtual machines. Users may then telnet to the virtual machines and access the command line via the screen reader. Virtualized GUI based operating systems are not easily accessible to the assistive technology when installed behind the console switch.

The physical layout of the remote laboratory equipment is depicted in Figure 3.

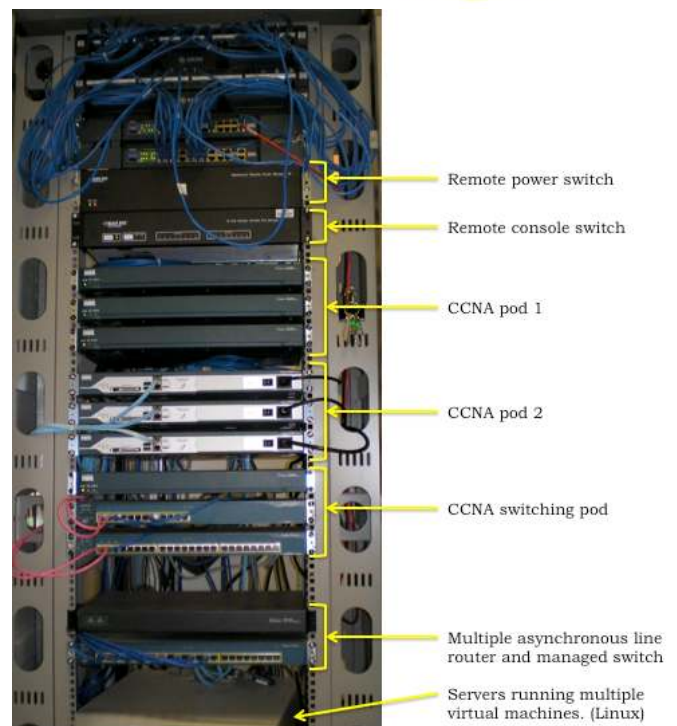
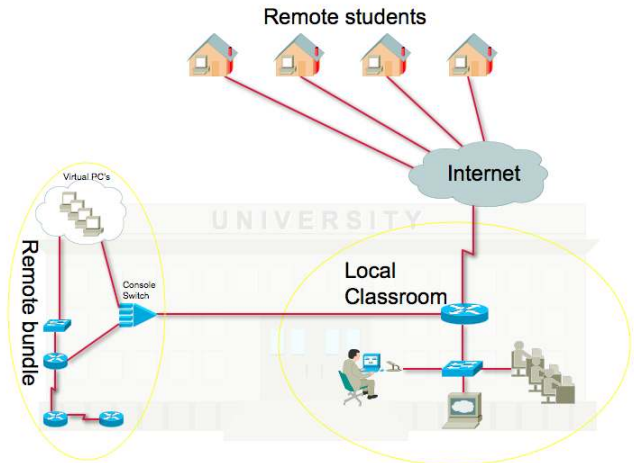


Figure 3: Teaching environment (top) and physical remote laboratory equipment layout (bottom)

Figure 4 illustrates an active telnet session logged into the remote bundle. As the routers are on their own network, with remote access attaching only to the serial ports, this system does not offer any security risk to the institution utilizing it. Once the student has authenticated with the console switch (simple plain text password) a list of available equipment is displayed, as shown in Figure 5.



Figure 4: Active console session

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[Murray-2::~] iainmurray% telnet 134.7.43.171
Trying 134.7.43.171...
Connected to 134.7.43.171.
Escape character is '^]'.
    
```

Enter Password: *****

PORT STATUS: Version 3.0, Site ID: Curtin -o o- --oo o- -o oo -o

PORT | NAME | PASSWORD | STATUS | MODE | BUFFER COUNT

PORT	NAME	PASSWORD	STATUS	MODE	BUFFER COUNT
09	Router1	(defined)	Free	Any	0
10	Router2	(defined)	Free	Any	0
11	Router3	(defined)	Free	Any	0
12	WKS1	(defined)	Free	Any	0
13	WKS2	(defined)	Free	Any	0
14	WKS3	(defined)	Free	Any	0

Figure 5: Remote bundle equipment list

Several commands are available and are listed in Table 1. Connection to equipment is made via the /C n command, where n = required equipment port number.

TABLE I. CONSOLE SWITCH COMMAND MENU

Display Options	
/S /SD	Port Status
/W	Port Parameters (who)
/J	Site ID
/H	Command Menu (Help)
Control	
<Enter>	Enter Command Mode
/x	Exit Command Mode
/C n	Connect to Port (n: Port# or name)

As the booking system was incomplete at the time of

writing, a virtual classroom was utilized as a method of ensuring students knew if the equipment was in use. When undertaking a laboratory, students logged into the Ventrilo server (a voice communication application designed for on-line gamers) and entered the appropriate channel, as shown in Figure 6. In this way students not only can tell if a particular bundle is in use but may also conduct laboratory sessions collaboratively with other students.

Power cycling of equipment is undertaken by authenticating first to the console switch and connecting to the remote power switch. The power switch may then be used to power down individual devices within the bundle. This is usually done with a secondary telnet session, allowing access to the router/switch to be power cycled and therefore the boot process to be interrupted (as in the case of password recovery laboratories). Each device may be powered on, off or rebooted. Figure 7 illustrates the process of remotely rebooting a router.

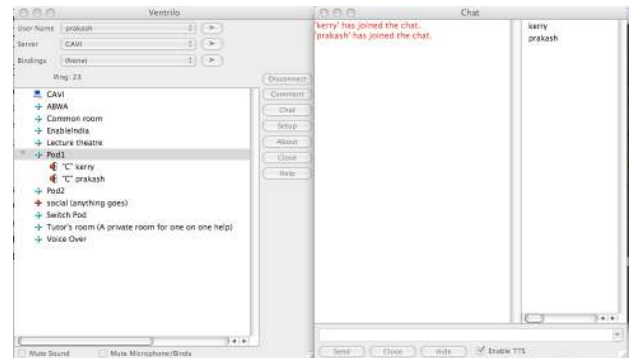


Figure 6: Ventrilo session (note users in the "Pod 1" channel)

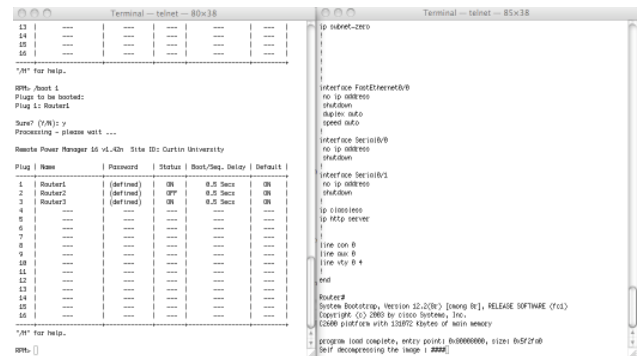


Figure 7: Remotely rebooting the router

Once connected via telnet, students may configure routers, switches and workstations in the same manner as if physically present. One such session is shown in Figure 7. Although this system allows laboratories to be completed, including e-Labs it has several shortcomings. These include the lack of a formal booking system, leading to students attempting to access the limited resources while others are engaged in laboratory sessions and it does not give students experience with the physical cabling of network systems. To

assist students with understanding the physical aspects of cabling, recorded audio demonstrations of the physical features of cables, connectors and their locations on switch and router hardware are conducted. In these demonstrations, a local vision impaired student conducts a supervised cable lab, describing in detail what they “feel” and how connections are made, in much the same manner as video is utilized for sighted students.

VI. INETSIM NETWORK SIMULATOR FOR APPLE OS X

iNetSim is a accessible network simulator, created to allow both vision-impaired and sighted users to complete CCNA 2 laboratory sessions without access to the networking hardware [30]. Existing software used in the CCNA course for network simulation and laboratory practice (Packet Tracer) and the eLabs is not accessible to those with impaired vision as it utilizes images of network topology, allows only mouse selection of network devices and tools and is incompatible with screen reading software. In contrast, iNetSim has been developed to be accessible by blind and vision impaired users in addition to those with normal vision. All user interface and network topology elements are accessible via the Apple screen reader (VoiceOver) keyboard shortcuts and provide a meaningful response when read by VoiceOver. Network simulators usually rely on the use of a mouse to add simulated communication links between devices, place network devices on the work area canvas, select configuration options and view simulation results. To connect two devices with a communications link, the user must generally click on icons for the simulated devices and drag the connection to its end point, another network device under normal circumstances. As this is usually not possible for vision-impaired users, iNetSim also incorporates the use of tables for connecting devices. Tables are used to alter a device’s location in the topology area, and configure ports and links. Tables are used as navigation with speech prompts, as these can be accessed with VoiceOver shortcut keys and cursor keys. iNetSim can be used solely with the keyboard, therefore the eye and hand issues faced by vision-impaired students can be avoided. As a GUI is also available, sighted iNetSim users can alternatively use a more traditional drag-drop mouse-based interface.

The system is capable of representing several generic network devices including routers, switches, hubs and PCs. Each device must be configured via a command line for correct operation. Figure 8 illustrates the application running with the textual command line terminal session to Router0 open. Note that the IP address on Router0, interface S1 is set to the same value as in the port table (highlighted) under the main canvas. Selecting values from the drop down boxes or edit fields in the main application window has the same effect as entering the command line configuration. Changes made with either method will be reflected

throughout the application. This allows rapid basic configuration to be undertaken by the instructor so that students may concentrate on the particular task in the session.

Each device may have several ports of different types including Ethernet, serial and console. The user creates a connection by specifying two ports to connect and a cable type. Removing a connected port disables the connection the same way unplugging a cable would in a real network. The command line interface to devices also provides control and feedback over the simulation. The interface acts in a similar way to the operating system for that device type (e.g. a generic DOS-like system for PCs and Cisco IOS for routers). A subset of the commands applicable to CCNA 2 allows the user to display and modify device configuration, establish routing protocols and ping, Traceroute or telnet to other devices. iNetSim maintains a representation of routing tables to simulate these tasks correctly.

A completed laboratory is depicted in the screen capture illustrated in Figure 8. Note the configuration entered in the terminal screen matches the configuration in the tables and the successful pings from both the routers and workstations.

A. Packet Tracer Accessibility

iNetSim was successful in its aim of illustrating that network simulators may be made fully accessible if accessibility is built into the design stage of application development. However, maintaining and building a separate simulator for use by the vision impaired is not feasible. Any such application would lag development and features of commercial, well resourced projects such as Packet Tracer, hence it was decided to develop an external application to connect to Packet Tracer utilizing the newly released APIs and multi user features. Initial development has aimed at examining the flexibility and ability of the framework underlying the Packet Tracer application development environment. The information obtained was then used to decide on the feasibility of an external application for vision impaired people, allowing them to use and manipulate the Packet Tracer software package to carry on networking simulation, particularly where the CCNA curriculum is concerned.

Although Packet Tracer is not intended as a substitute for real equipment, it allows students to practice using a model of the Cisco Internetwork Operating System (IOS) command line interface and provides visual, drag-and-drop problem solving using virtual networking devices. This hands-on capability is a fundamental component of learning how to configure routers and switches from the command line. Students can see how to configure and connect networking hardware while confirming systems design. Instructors can create their own self-evaluated activities that present immediate feedback to students on their proficiency

in completing assignments.

Starting from version 5.0 onwards, Packet Tracer supports external applications as well as user connections. In the case of multiuser connections, an instance of Packet Tracer on computer A can communicate with another instance of Packet Tracer on computer B. Therefore, users in different places can have collaborative and competitive network building, using the real network to carry the virtual packets.

Based on Packet Tracer Messaging Protocol (PTMP) and Inter Process Communication (IPC) the external application developed communicates with an established Packet Tracer instance on the same computer or another on the network, thus it is only necessary that the developers maintain an accessible client that communicates with the commercial simulation software.

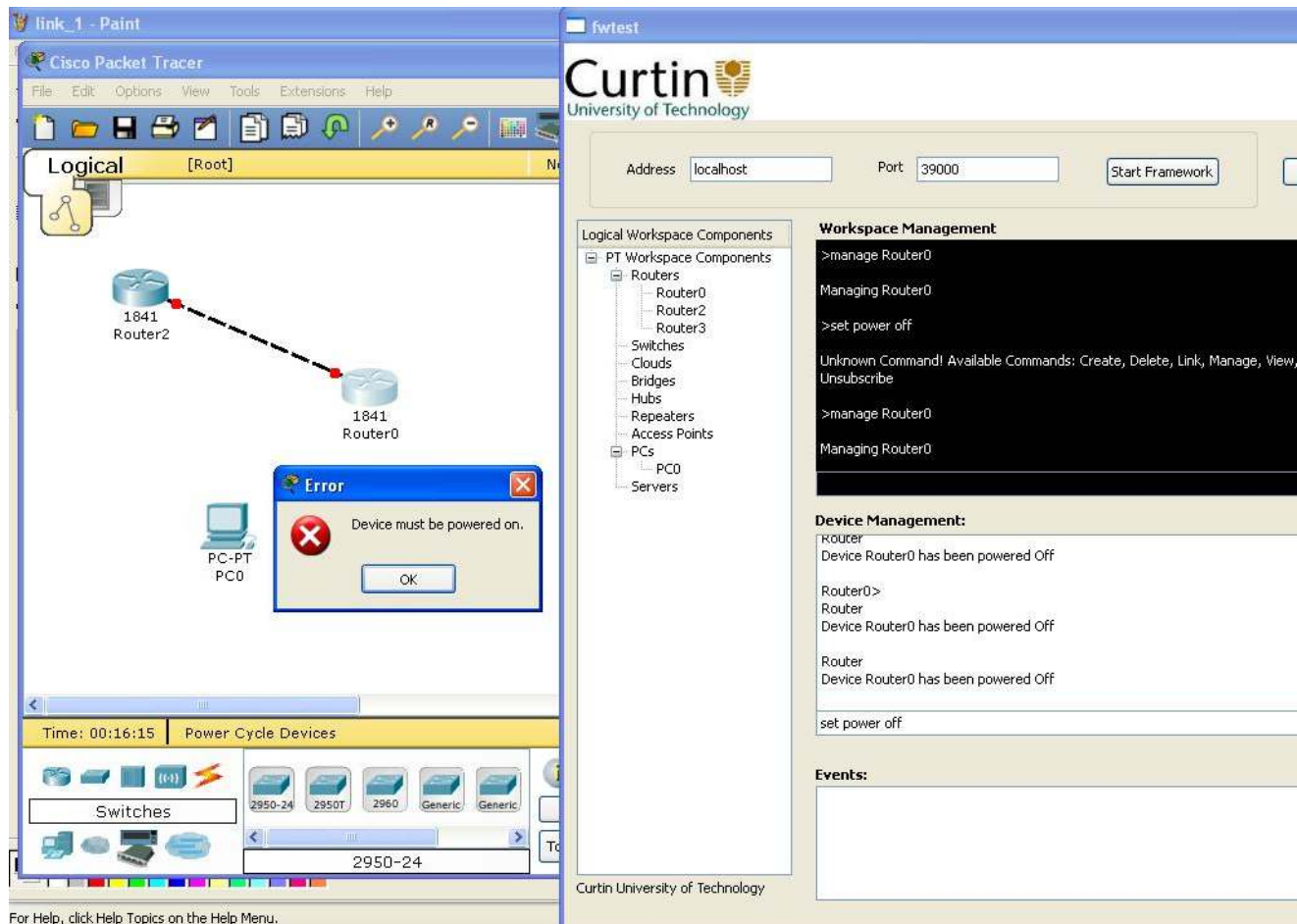


Figure 8: External application communicating with an instance of Packet Tracer

VII. PACKET TRACER EXERCISES AND eLABS

The combination of access to real network hardware and a practice environment in the simulation software has shown to be a valuable resource. CAVI has converted Discovery Packet Tracer exercises and eLabs (from CCNA version 3.1) to a format that may be run on the remote bundles so that students receive a similar learning experience to that of their sighted peers. These conversions include descriptions of graphics and network topologies, starting router configurations that are pasted into the routers and accessible

instructions on laboratory procedure. eLabs are utilized to communicate a single learning outcome from the curriculum chapter being currently studied without the necessity of the student creating multiple complex router configurations. Vision impaired students took significantly longer than their sighted counterparts to complete each eLab due to the necessity of connecting to the remote bundle, pasting configurations into the required network prior to commencing the laboratory session. However, students found that completing a set of eLabs reduced this setup time considerably. Trials of eLabs with instructors, both vision

impaired (n=3) and sighted (n=4) established that there was no perceived difference in the user experience once configurations were copied to laboratory equipment. On a scale of 0-5 where 0 = of no use, 5 = very useful, students (n=13) rated the usefulness of eLabs at an average of 4.6 (median = 4.5). The disadvantage of eLabs is primarily in the preparation involved, each piece of equipment used in a particular session required a configuration file to be created and tested. Instructions needed to be transcribed from the Flash files, tested by qualified personnel and altered to suit use on the remote bundle. In excess of 180 individual files were created. A further disadvantage is in cases where a large number of network devices are required, simplified topologies were used due to restrictions on the quantity of network devices in the remote bundle.

VIII. CONVEYING GRAPHICAL NETWORK TOPOLOGIES TO THE BLIND

A. Network Dominoes

The concept of a tactile method of displaying network devices and interconnections was initially well received by students in the pilot study. A survey of totally blind users of the Network Dominoes (see Figure 9) showed that students rated the usefulness highly at 4.4 out of 5 (n=6). An interesting item was raised in the comments section of the survey, as detailed in the following quote.

“The network dominoes are interesting for showing students what the network shapes look like. This can be useful for if they have a sighted person without any networking knowledge trying to explain a diagram to them, they are able to tell the sighted person what the shapes are.”

The ability to identify standard graphic icons is of obvious import given that it is expected that students will be in mainstream employment and required to interact with their sighted peers. Whilst the network dominoes achieved the desired result of communicating topologies, it was decided to discontinue their use in the later iterations of the courses. The primary concern with the network dominoes became apparent with the inclusion of students undertaking the courses remotely. Remote students would connect the dominoes in the manner that they thought was correct, but on occasion was significantly different to the intended topology. As the instructors have no method of checking the said topology, being both blind and geographically separated from the tactile topology, errors in construction would not be identified and thus lead to possible misconceptions by students. A secondary issue was that of cost, both in production of the full range of network device objects and that of distribution of multiple sets. If the cost of production could be reduced, use of these devices should be explored in future trials.

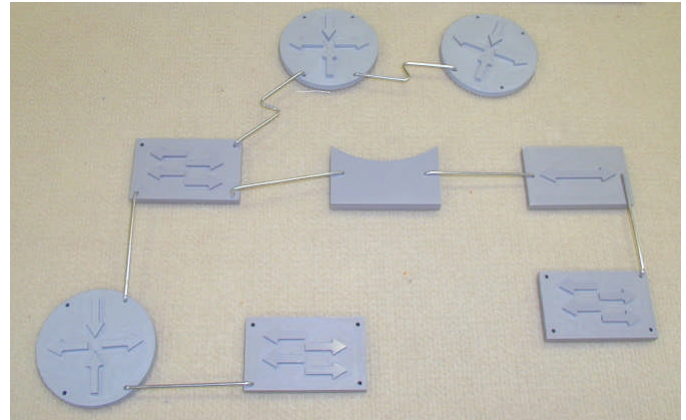


Figure 9: Network Dominoes

B. Tactile Diagrams

PIAF, Picture in a Flash, is an assistive technology device that uses a controlled heat source to imprint images or diagrams onto heat sensitive paper which then swells to reproduce a raised representation of the image. The output of PIAF is intended to allow the vision impaired to see by feeling tactile graphics. While in many situations this product provides a satisfactory solution to gaining an appreciation of an image or basic diagram it does not meet the requirements necessary to impart understanding of detailed information taken from complex technical diagrams. As Dulin [29] identified, raised line drawings may increase the blind individual's spatial cognition and communicate information from graphics that would otherwise be inaccessible, several issues were noted when utilizing this media in the context of technical drawings. Many of the network diagrams, in order to fit on the A4 capsule paper, required the network device icons to be of limited dimensions (approximately 30mm by 30mm) the tactile resolution of the human senses made it difficult to identify or differentiate between similar objects, for example hubs and switches. A significant number of tactile diagrams were produced, utilizing the PIAF system, in the pilot study stage of the research (in excess of 150 individual diagrams and charts). Totally blind students within the pilot study were surveyed (n=6) on the suitability and usefulness of this style of graphic representation with the disappointing results, given the cost and time taken in production. Overall on the scale of 0 to 5 an average result of 2.4 (mean of 2.0) was returned. The physical bulk and material cost of tactile pictures made it difficult and inefficient to distribute up-to-date material to remote students, particularly when compared to electronic text descriptions.

PIAF along with the tactile assistive technology devices suggested as being useful to vision impaired students proved to be unsatisfactory in meeting the needs of the vision impaired student studying to the Cisco course materials. The complexity of images and diagrams in the required teaching materials and the individual health issues of students proved

these devices/methods unsatisfactory. Given the logistical difficulties of shipping significant quantities of tactile pictures and overlays to various countries the costs become prohibitive as the class size increases.

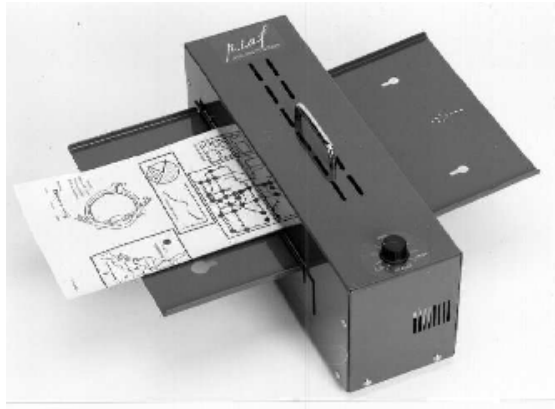


Figure 10: PIAF Tactile Printer and Nomad (Source: http://www.brailleworldindia.com/braille_tactile_graphics.htm#PIAF)

The challenges relating to teaching materials focused directly on how best the students could gain an understanding of course materials. While not all, many complex computer related technical images and diagrams rely on the use of color, which is difficult to represent on tactile media. The main difficulty with these devices or tactile media was that the demands being placed on them were inconsistent with their ability to meet teaching requirements.

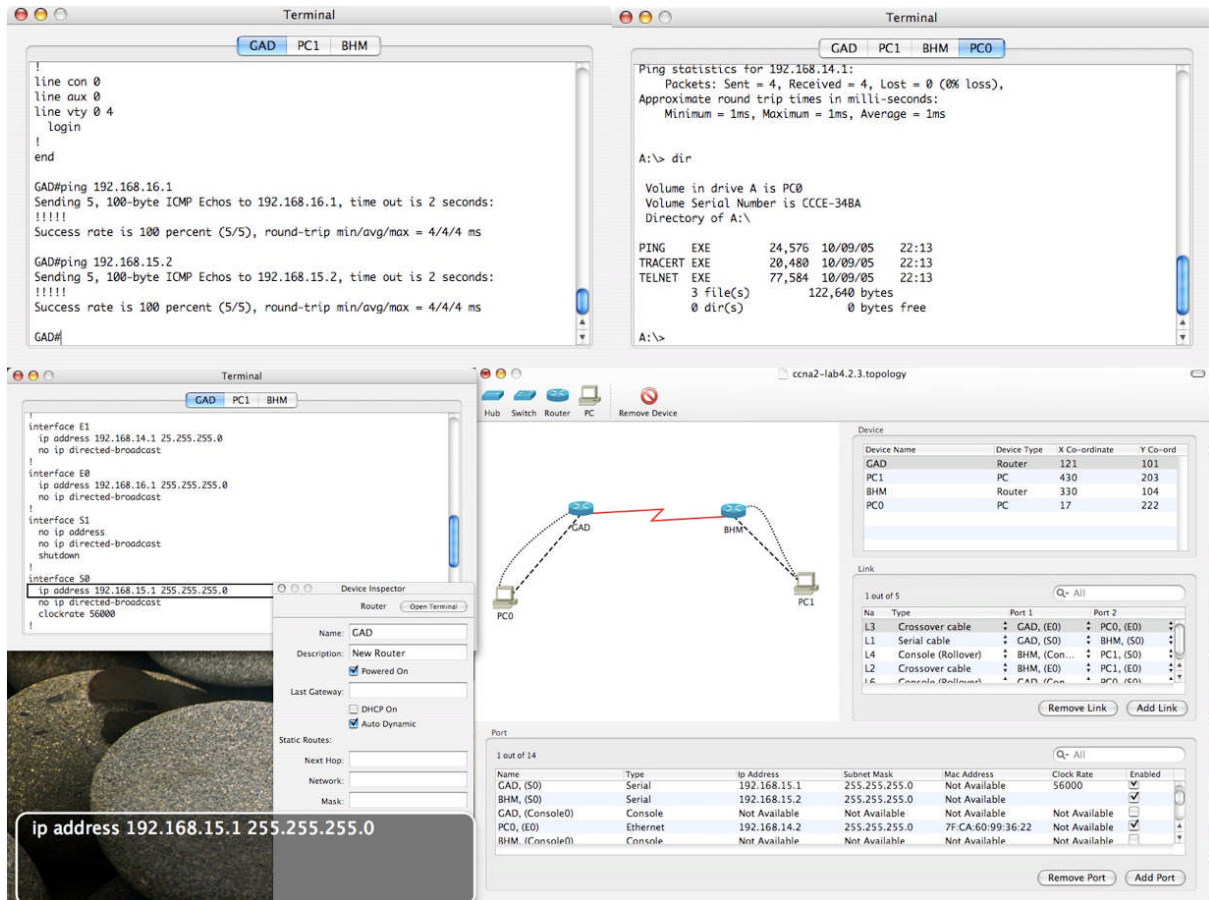


Figure 11: iNetSim with command line terminal session open. The text in the floating window shows the text read by VoiceOver

IX. STUDENT RESULTS

The following discussion covers an analysis of how

effectively and efficiently problems defined in relation to remote teaching of vision impaired students were addressed. [29] Definitions of effectiveness and efficiency as the basis

for these evaluations are:

- Effectiveness is evaluated by determining how well the solution achieves the given objectives. In this context effectiveness is measured by determining whether the vision impaired students studying the converted e-learning courses achieved the same outcomes as able-bodied students studying the unconverted courses.

- Efficiency is evaluated by determining any increase or decrease in the level of the resources used to achieve the stated objectives. In this context efficiency is measured by ascertaining whether the difference in costs for teaching methods and tools between the vision impaired accessible environment and the traditional Cisco e-learning environment is minimal for the same level of output.

Each mode of presentation is evaluated via a ranking of 0 through 5, where 0 denotes “no use whatsoever”, 3 gives the same or similar outcomes or resources, and 5 shows a significant increase in outcomes or significant decrease in resources. An acceptable solution should rate at least 3 and a summary of the ratings is presented in Table 2.

TABLE II. EFFECTIVENESS OF SOLUTIONS

Requirements	Potential Solution	Effectiveness (same outcomes)	Efficiency (more or less resources)	Comments
1. Lack of student mobility	Virtual classroom	4	5	Highly scalable without increasing resources
	Remote Bundle	5	4	Slightly more complex to use. Reduces cost of distributing multiple laboratory pods. Equipment available 24/7
2. Inclusion of remote students	Virtual classroom	4	5	No realistic limitations on lecture size
7. Cannot access laboratory exercises	e-Labs	3	3	Labour intensive conversion process.
	Remote labs	5	4	No access to physical cabling. 24/7 availability

				of equipment. Lower cost to small Academies (shared resource)
	iNetSim	3	2	Proof of concept only.
	Network dominos	3	2	High production cost and bulk.
10. network topology/ simulation software	Network dominos	2	2	High production cost and bulk. Not interactive and do not simulate the operating system.
	iNetSim	3	2	Modification of Packet Tracer user interface to overcome the access issues.

Overall results for students in the 2007 intake are shown in Table 3 and Figure 12.

TABLE III. STUDENT RESULTS

Course	Demographic	n	Comments
CCNA 1	Population	214,499	Average across all questions
	Vision Impaired	24	
	Sighted	19	
CCNA 2	Population	67,601	Average across all questions
	Vision Impaired	23	
	Sighted	19	
ITE 1	Population	61,386	Average across all questions
	Vision Impaired	23	
	Sighted	19	
ITE 2	Population	28,484	
	Vision Impaired	22	
	Sighted	32	

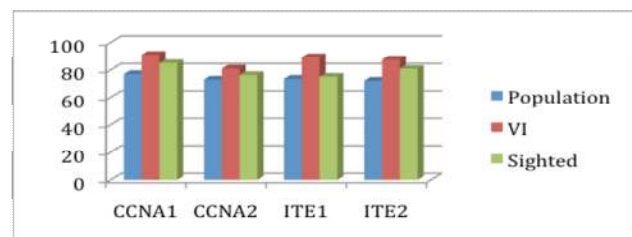


Figure 12: Student Examination Results

As can be noted by the graph in Figure 12, the vision impaired group consistently scored better across the full range of courses when compared to the sighted groups. The

population group may not be representative as no level of support, availability of resources and other relevant information is available for this group. The sighted group may be directly compared as they consisted of students taught at Curtin University of Technology as part of their coursework in the Bachelor of Technology (Computer Systems and Networking) and as such had a comparable educational background and access to resources such as laboratory equipment and information.

X. CONCLUSIONS

Whilst the use of the remote bundle overcomes many of the limitations imposed by delivering CCNA laboratories to remote blind and vision impaired students, further work is required to improve functionality and ease of use. A method of booking and authentication of users is currently under development as part of a “front end” web portal to streamline the connection to network devices.

iNetsim was successful in proving that network simulators may be made accessible. However, it is now considered that, with the availability of Packet Tracer API's and the Packet Tracer Messaging Protocol a possible way forward in accessibility is to develop an accessible extension (a user interface) that communicates with Packet Tracer. This would have the benefit of utilizing the superior Packet Tracer library of devices and protocols and the support and continuing development without duplication of resources.

The solutions presented in this paper assist in overcoming the laboratory issues involved in remote delivery to vision impaired students however there are many significant obstacles in accessibility that have also been addressed in the CAVI project [31]. The CAVI classes offer a holistic environment tailored to cater for blind and low vision students without compromising course quality and student outcomes. Using the environment and tools established by CAVI students with severe vision impairment are able to undertake the same Cisco courses as their sighted counterparts.

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