Cisco Packet Tracer as a teaching and learning tool for computer networks in DWU

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Abstract

There is a growing demand in the global economy for IT professionals with networking skills. One organization that supports this growing economy is the Cisco Networking Academy. Cisco has a large share of the hardware and software market for networking equipment. Cisco's comprehensive networking technology teaching and learning software, Packet Tracer, plays a key part in opening up this world of possibilities and connections. Against a backdrop of diverse data network simulation software and unreasonably high costs of acquiring physical laboratory hardware for teaching and learning, Packet Tracer emerges as an excellent and freely available network-simulation tool that can make learning networking both an interesting and motivating experience for students and instructors among academic and training institutions in PNG, especially in DWU.

Key words: networking, Cisco Packet Tracer, IT professionals, cisco academy, ICT

Introduction

Computer networks have become a fundamental tool of today's corporate environment. "Computer networks consist of devices that provide communication paths between electronic machines to create local networks inside buildings as well as the interconnection of networks in such structures as campuses and the Internet" (Frezzo, Behrens et al. 2010). As Lammle (2010) suggests, "computers have become invaluable to us personally and professionally. Our society has become highly dependent on these resources and on sharing them with each other. The ability to communicate with those we need to whether they're in the same building or in some far-away land completely hinges on our capacity to create and maintain solid, dependable networks" (Lammle, 2010). To have such skills that will enable an IT professional to create and maintain networks requires rigorous training. It is a demanding field of expertise since the efficient operation of many business organizations today rely upon the smooth operation of its computer network.

Papua New Guinea (PNG) in its Vision 2050 statement emphasized the importance of "training of human capital, in the areas in which they operate". (National Strategic Plan Taskforce, 2009, p. 13). "Skills have become the global currency of 21st century economies. Without sufficient investment in skills, technological progress does not translate into productivity growth, and

countries can no longer compete in an increasingly knowledge-based global economy" (Lee, 2013).

A study on the evolution of the networking skill's gap in Asia/Pacific by IDC, a premier global market intelligence firm reported that companies could be experiencing shortages in certain networking competencies. "As a general practice, most companies hire a certified professional to oversee a team of non-certified engineers that learn the basic procedures as part of on-the-job training. While practical experience is undoubtedly valuable in solving issues, structured and formal training can bring more value to the company and allows personnel to acquire other essential and emerging skills." (Lee, 2013).

For a developing country, this highlights a challenge for training and for academic institutions as the demand for IT professionals continues to grow. Understanding how computer networks are designed, how they function and how they can be managed is an indispensable skill that an IT professional must acquire.

Within this context, this paper seeks to highlight some basic challenges of teaching computer networks in a developing country, then to present key features and benefits of Cisco Packet Tracer (PT) and its relevance to teaching and learning computer networks in PNG, especially Divine Word University (DWU). It begins by highlighting the challenges and introduces the DWU Cisco Networking Academy. The role of the network simulator Packet Tracer is then discussed with key features of version 6.2 presented and illustrated with a simple real world case study.

Challenges of teaching computer networking

Teaching computer networking in schools, colleges and universities has only become more challenging especially in a developing country. "It is often difficult to motivate students to learn computer networking due to its dry and boring theories and many students appear to think the subject rather technical and tedious" (Chung Hsien, 2007). "It could be that the topics are rather abstract when they are presented using a traditional lecture format" (Cabarkapa, 2015).

In the Information Systems (IS) degree program at DWU, the computer networking units are introduced in the second year of studies where students will be expected to have achieved a level of computer literacy to enable them to cope with the many challenging concepts required in networking. Many of these students come from a rural area or high schools that have very limited access to computers. As Leh and Kennedy reported in a 2004 survey concerning Papua New Guineans' views and their use of technology, IT and PNG's curriculum:

> "Outside of the few universities in the country, the schools in PNG are for the most part not equipped to use overhead projectors, videos, copiers, computers, the Internet, and so on, except on a very limited basis." (Leh and Kennedy 2004)

Since this survey report was published, the present situation of many schools in PNG remains unknown but it seems very little might have changed. This will continue to be a challenge for introducing computer studies at DWU. There is, to a certain extent, a prerequisite of knowledge of the basic computer concepts before students embrace the study of computer networks.

"Another challenge is the lack of basic infrastructure, and need for strong institutional support which leaves developing nations behind" (Leh and Kennedy, 2004). Institutional support in terms of finance may be very limited, thus schools may not be able to acquire high-end networking equipment for practical work. Complicated banking regulations for foreign exchange also make the procuring of networking devices for student use difficult. The networking component for our DWU programs with IT strands over the past several years has had to rely heavily on donated equipment from various supporters and sponsors including individual support from the head of department. Easily available, structured and user-friendly curricular and educational tools also add to the list of challenges. It is in this context that the role of the DWU Cisco Networking Academy is introduced.

DWU Cisco Networking Academy

As networking systems continue to evolve in complexity, new curricula and educational tools are emerging to facilitate teaching and learning related to networking technology. The Cisco Networking Academy program is designed to keep pace with the evolution of networking systems by providing up-to-date innovative curricula and educational tools that help students understand the complexities of information and communication technologies (ICT).

This program is a global endeavor to support the acquisition of ICT skills associated with computer networking, especially in underserved communities. The program is a cooperative undertaking between Cisco, the Cisco Learning Institute, and approximately 9,000 public educational institutions across more than 160 countries (Frezzo, Behrens et al., 2010). At present, there are only two recognized Cisco Academies in PNG: DWU and University of Technology.

Due to the growing demand in the global economy for IT professional with networking skills, Cisco has embarked on a program of supporting this growing economy through its accredited Cisco Academy partnerships with training institutions, universities and organizations around the world. Research from Synergy shows that Cisco has a larger share of the hardware market reaching roughly 65 percent and 70 percent respectively. (Reno, 2013).

Through these academies, Cisco helps provide the necessary skills to students around the world, to improve their career and economic opportunities, and to

increase their access to the knowledge economy. The Academy program delivers a comprehensive learning experience to help students develop ICT skills for entry-level career opportunities, continuing education, and globally recognized career certifications. The curricula also help students build 21st century skills such as collaboration and problem solving by encouraging practical application of knowledge through hands-on activities, (chapter exams, quizzes) and network simulations. (Cisco Packet Tracer Data Sheet, 2010)

DWU, on the 11th of November, 2014 was accredited as a Cisco Networking Academy with the support of the Royal Melbourne Institute of Technology (RMIT) as its Academy Support Centre (ASC). Several of our teaching staff involved in teaching IT strands underwent two two-week intensive instructor training programs in 2015 and 2016, for the R&S CCNA1-2 and R&S CCNA3-4 programs. Teaching staff as well as several DWU ICT department staff successfully passed theory and practical exams and were accredited as Academy Instructors. The teaching staff who were accredited as instructors are now involved in delivering the Cisco Certified Network Associate (CCNA) program.

The Academy has its own online learning portal named Netacad and is used together with the DWU Moodle Learning Management System (LMS) to deliver the CCNA Routing & Switching (R&S) curriculum version 5.3. The CCNA R&S curriculum has been integrated into our networking strands with each preceding module serving as a prerequisite for subsequent modules. Strong institutional support as previously highlighted plays a vital role in the success of such a program as demonstrated by the purchase and use of good quality hardware equipment (Figure 1) in a dedicated academy laboratory.

Figure 1. The initial 12-unit equipment rack on the left, with a new router (centre) and Voice over IP phones (VOIP) (right) as additional equipment for student laboratory work simulating real works situations.

The Cisco networking program has several pathways. However, one that is widely known in the industry is the CCNA program which is the pathway we are undertaking in our networking strand. In the context of equipment provision, we now consider the availability of network simulators.

Role of the Packet Tracer simulator

As Frezzo, Behrens et al (2010) have asserted regarding teaching laboratory equipment and learning:

> "even when sufficient equipment is present to provide the desired amount of hands-on practice for skill acquisition, the networks used will typically not be able to cover the scope of desired complexity. One might describe this situation as a high student-to-network ratio. Furthermore, while academies are required to have a hands-on component including the presence of networking equipment in the classroom, the required minimum amount of equipment cannot always provide the desired amount of practice if the class is large or the students require extended practice for lack of outside experience" (Frezzo, Behrens et al. 2010).

This is also our experience now in the DWU Academy which is also indicated in our student evaluations.

Information Technology (IT) or Information Systems (IS) students who study networking must be able to explain the fundamentals of how computer networks function. To achieve this learning goal, they have to spend many hours involved in practical applications designing, configuring and implementing a computer network. Satisfaction in this endeavor is only achieved when available hardware is adequate enough to enable individual practice on equipment software configuration.

An alternative approach is to provide students with network simulation software, although this is not meant to entirely replace hardware. However, as Cabarkapa (2015) suggests, "it represents a useful and cost-effective approach to understand concepts of computer networks, protocols and applications better than traditional tools". As previously noted, the simulator to which this paper refers is Packet Tracer (PT) where laboratory activities provide the element of experiential learning with work-ready skills that industry and employers desire. The simulator doesn't require all the physical networking devices to be present; it visually simulates networking equipment through onscreen icons to mimic hardware (Figure 2).
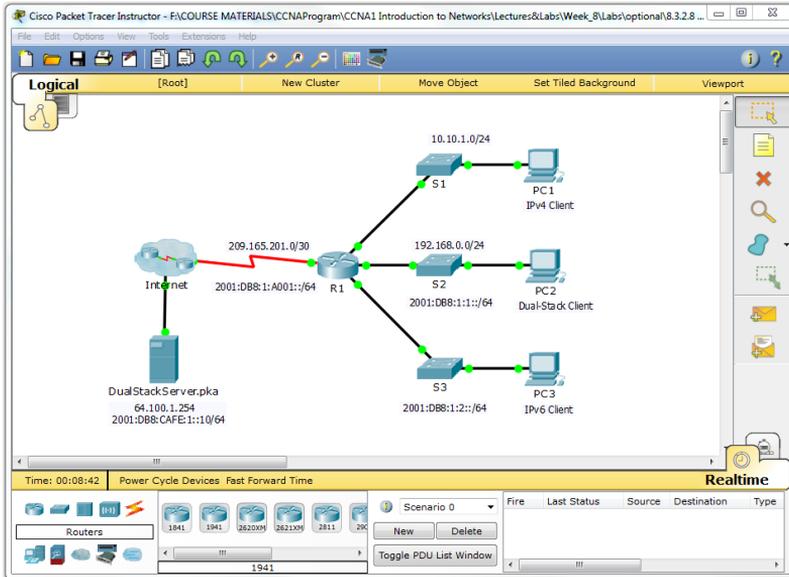
Figure 2. A sample PT window showing simulated networking network topology in the workspace with various devices, derived from the selection pane, now available for configuration by simply clicking on the appropriate icon**.**

Clicking on an icon (Figure 3) provides access to the device Internetworking Operating System (IOS) which is the same operating system as is installed on the equivalent hardware device. Cabling is also part of the simulation which effectively connects device operating systems via software.
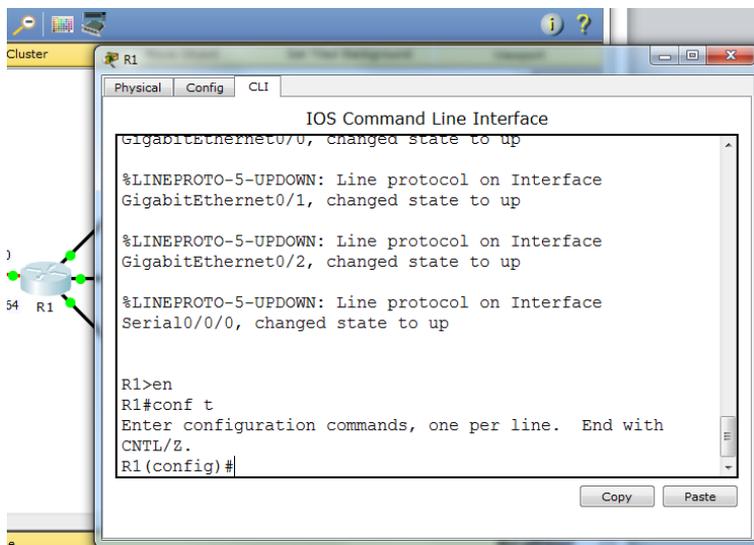
Figure 3. Command Line Interface (CLI) tab where IOS of a switch or router can be accessed and commands entered.

Clicking on the device gives the student a dialog box (Figure 4) from where commands can be entered, configurations can be completed (Config and CLI tabs) and, on the physical tab, even a physical view of the actual device is available.
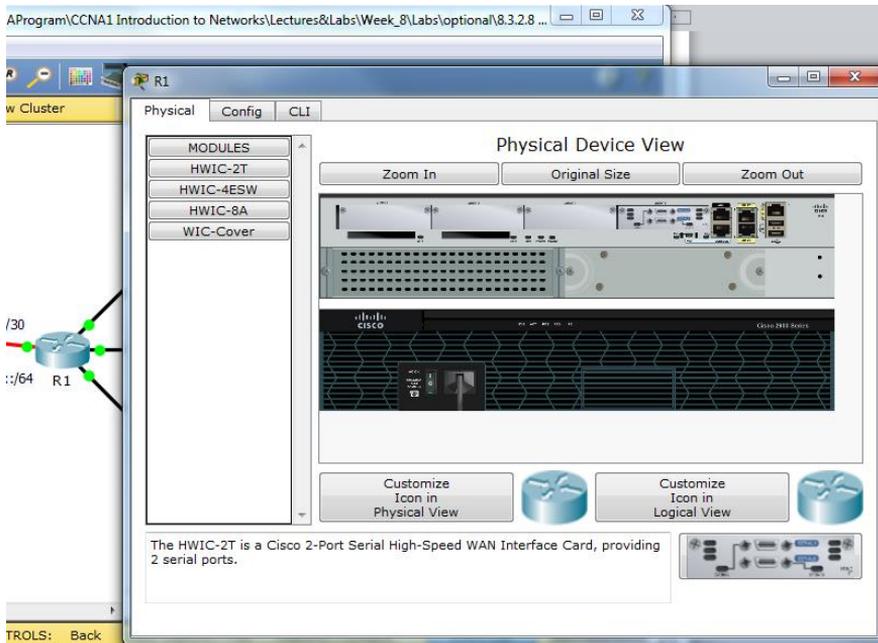
Figure 4. Using the physical tab, a view of the physical device is presented.

PT simulates networking protocols, and processes with real-time updates of underlying network logic and activity to complement classroom equipment. Because it simulates real equipment, users can create virtual network worlds that could not realistically be made available physically in the classroom. The combination of realistic simulation and visualization experiences with assessment allows students to explore concepts, conduct experiments, and test their understanding in a safe, simulated learning environment.

Choice of Packet Tracer

There are several software applications that can simulate designing and analyzing computer networks. These include Boson NetSim, Boson RouterSim both of which are commercial, the free Graphical Network Simulator (GNS3) and Wireshark, a free network protocol analyzer. However, Packet Tracer's growing popularity can be attributed to the fact that it is an open source freely available software; it is supported and maintained by the major vendor in networking hardware; it supports many core technologies and protocols required to build a small to complex network; it provides a visual connection between OSI model protocols of each network layer helpful in teaching; and it

is lightweight in terms of not making excessive demands on the host PC's memory and CPU resources.

At DWU students are issued with laptops enabling those studying computer networks to use PT both inside and outside the classroom, to learn at their own pace, and at their own convenience. It includes several basic step-by-step tutorials that familiarize users with the product features and explain how to engage in simulations. Additional advanced tutorials are available for download from Academy Connection available through the Help feature. Using PT for problem-solving and troubleshooting practice helps to open a world of practical networking knowledge as noted in the Cisco PT Datasheet:.

> "PT also helps instructors teach complex networking concepts by providing a visual demonstration of complex technologies and configurations, allowing instructors to customize guided activities that provide immediate feedback using the Activity Wizard. It provides instructors with an environment to facilitate teaching of complex CCNA-level technical concepts with capability to accommodate various learning activities such as lectures, individual and group lab activities, homework, assessments, games, network design, troubleshooting, modeling tasks, and case studies. It enables visualization, animation, and detailed modeling for exploration, experimentation, and explanation" (Cisco Packet Tracer Datasheet, 2010).

Key features

The Packet Tracer Network website indicates that Cisco Packet Tracer has seen the release of three different versions within the last two years. In February 2015 PT 6.2 was released in two versions - Student and Instructor. PT 6.3 was released on 22nd December 2015. This version is a maintenance version with Netacad login enabled at application startup. It replaced PT 6.2 Student and Instructor. The current version PT 7.0 is a stable version that does not require any Netacad login. It also has a number of new and exciting features, protocols and devices (Table 1) that are more geared towards Borderless Network Architecture and embracing Internet of Everything (Table 1). The table shows the new devices and protocols that have been included since PT 6.2 and up until PT 7.0.

**Table 1 New devices that have been added and protocols supported**

New Devices	Layer	Cisco PT Supported Protocols
ASA 5505 firewall with CLI configuration. Netflow collector as a desktop application in the server device. Cisco 819 ISR router with embedded wireless access point.	Application	FTP, SMTP, POP3, HTTP, TFTP, Telnet, SSH, DNS, DHCP, NTP, SNMP, AAA, ISR VOIP, SCCP config and calls ISR command support. Call Manager Express
	Transport	TCP and UDP, TCP Nagle Algorithm & IP Fragmentation, RTP
	Internet	BGP, IPv4, ICMP, ARP, IPv6, IPSec, RIPv1/v2/ng. Multi-Area OSPF,

3G/4G cell tower, Central Office (CO) server and 3G/4G support for end devices (smartphone, tablet, server etc.), 3 new routers; 829, 1240 and 819HGW routers.		EIGRP, Static Routing, Router Redistribution, Multilayer Switching, L3 QoS, NAT, CBAL, Zone-based policy firewall and Intrusion Protection System on the ISR, GRE VPN, IPSec VPN
	Network Access/ Interface	Ethernet (802.3), 802.11, HDLC, Frame Relay, PPP, PPPoE, STP, RSTP, VTP, DTP, CDP, 802.1q, PAgP, L2 QoS, SLARP, Simple WEP, WPA, EAP

Although there are quite a number of new features that have been included in this new version, a number of key features of interest will now be explored: the physical workspace, the simulation mode, the ability to insert interface cards, multiuser functionality, and the activity wizard. Whenever there is a new PT release or software update announced, Cisco publishes a datasheet on their website indicating what new features and technologies have been included or supported in the new release or update. The features presented here are taken from the Cisco Packet Tracer Datasheet (2010).

The physical workspace

Cisco Packet Tracer has two workspaces - logical and physical. The logical allows users to build logical network topologies by placing, connecting, and clustering virtual network devices. The physical workspace provides a graphical physical dimension of the logical network, giving a sense of scale and placement in how network devices such as routers, switches, and hosts would look in a real environment. The physical view also provides geographic representations of networks, including multiple cities, buildings, and wiring closets. Examples of these representations (Figure 5) display the logical and physical representation of the network our CCNA 4 students are tasked to design and build as part of their capstone project.
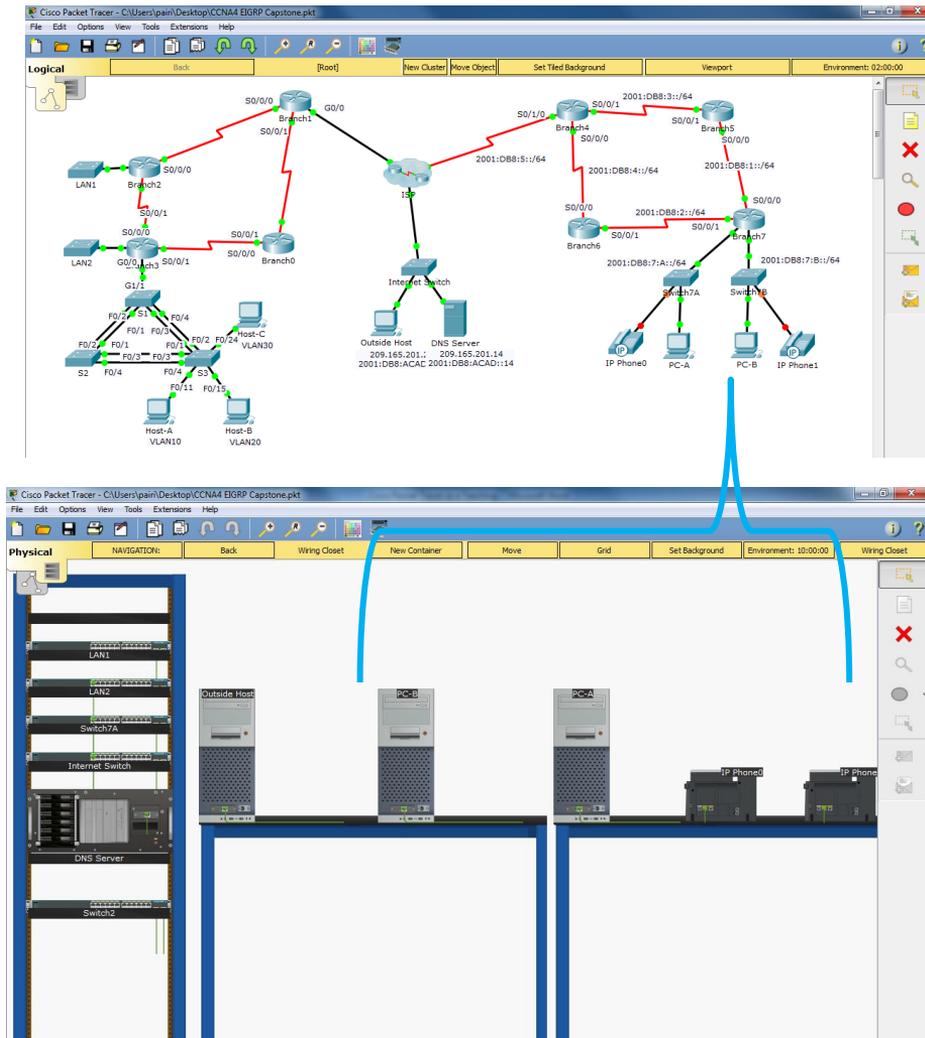
Figure 5. The second image illustrates the Physical Workspace of a selected portion of the network design shown above.

Packet Tracer Modes

Cisco Packet Tracer provides two operating modes to visualize the behavior of a network, real-time mode and simulation mode. In real-time mode the network behaves as real devices do, with immediate real-time response for all network activities. The real-time mode gives students a viable alternative to real equipment and allows them to gain configuration practice before working with real equipment. Its functionality can be described as:

> In simulation mode the user can see and control time intervals, the inner workings of data transfer, and the propagation of data across a network. Students can visually analyze a packet and its' details from the simulation mode. This helps students understand the fundamental concepts behind network operations. A solid

understanding of network fundamentals can help accelerate learning about related concepts. (Cisco Packet Tracer Datasheet, 2010).
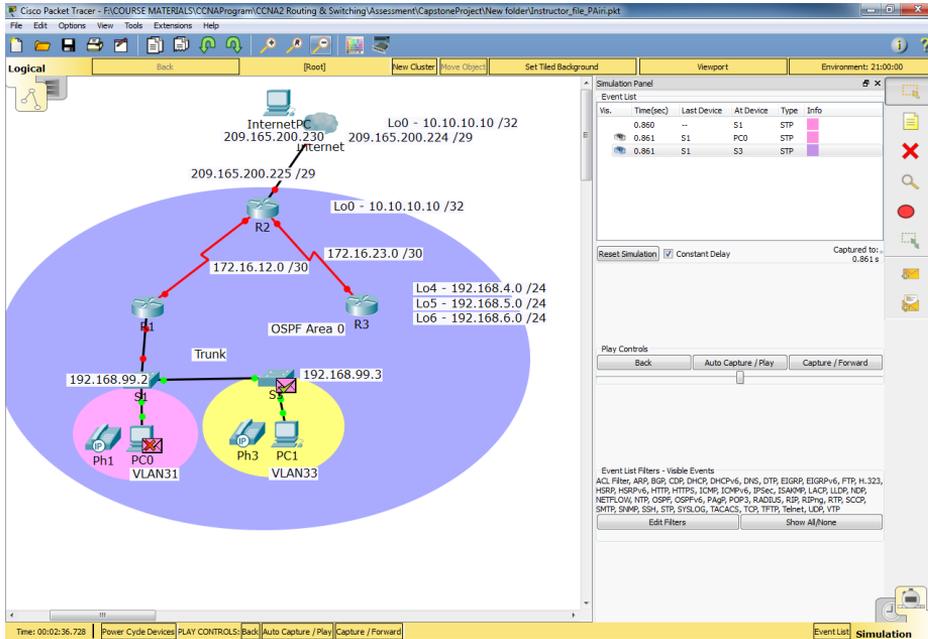

Figure 6. Simulation mode is illustrated in this figure. A basic packet can be sent from any sender device to destination and the route the packet takes can be observed in PT.

PT's simulation mode enables instructors to demonstrate processes that were formerly hidden to students. This processes cannot be easily seen in a physical production environment. These simulation capabilities can help simplify the learning process by providing tables, diagrams, and other visual representations of internal functions such as dynamic data transfers and packet content expansion. The simulation mode also decreases instructor presentation time by replacing whiteboard illustrations and static slides with real-time visuals.

Modular devices
Graphical representations visually simulate hardware and offer the ability to insert interface cards (Figure 7) into modular routers and switches, which then become part of the simulation.
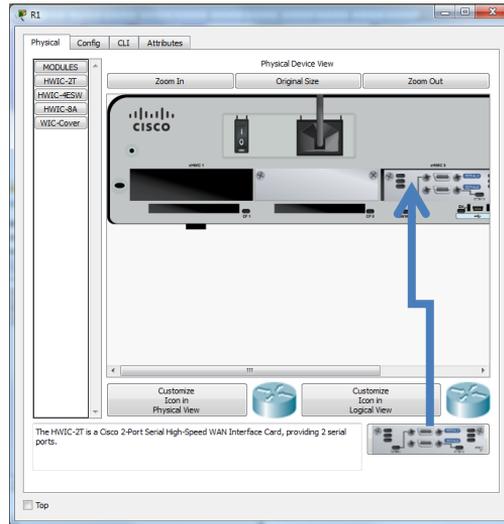
Figure 7. A module is selected and then inserted into the device.

Multiuser functionality

Multiuser functionality allows collaborative and social learning and is described as follows:

> Cisco Packet Tracer is a network-capable application, with a multiuser peer-to-peer mode that allows collaborative construction of virtual networks over a real network. The multiuser feature enables exciting collaborative and competitive interactions, providing the option to progress from individual to social learning and features opportunities for collaboration, competition, remote instructor-student interactions, social networking, and gaming. Multiuser functionality opens up a new world of social learning and collaboration possibilities (Cisco Packet Tracer Datasheet, 2010).

Instead of working alone, students in the classroom can collaborate and connect their networks running on their own machine to their colleagues' network through multiuser functionality. Figure 8 demonstrates two instances of PT running; LAN A can be on another PC while LAN B on a different PC also. Through multiuser, LAN A has been set on incoming while LAN B set as outgoing. The port visibility of LAN A and B is port 24 on the switch. This allows the two networks to peer via port 24.
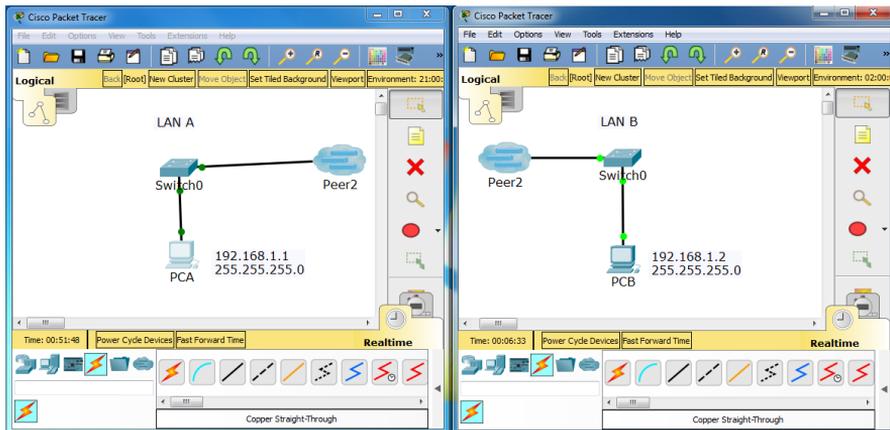
Figure 8. The multiuser functionality in Packet Tracer enables multiple networks on different computers to interact.

Activity wizard

The software comes in two main editions: the Student edition and the Instructor edition. The instructor edition provides activity authoring capabilities for the teacher. A feature called the Activity Wizard (Figure 9) allows instructors to author learning activities by setting up scenarios using instructional text, and creating initial and final network topologies and predefined packets. It also includes grading and feedback capabilities that provide immediate feedback to students. "With the wizard, it's also simple to customize lessons to address the needs of each class or student" (Cisco Packet Tracer Datasheet, 2010).
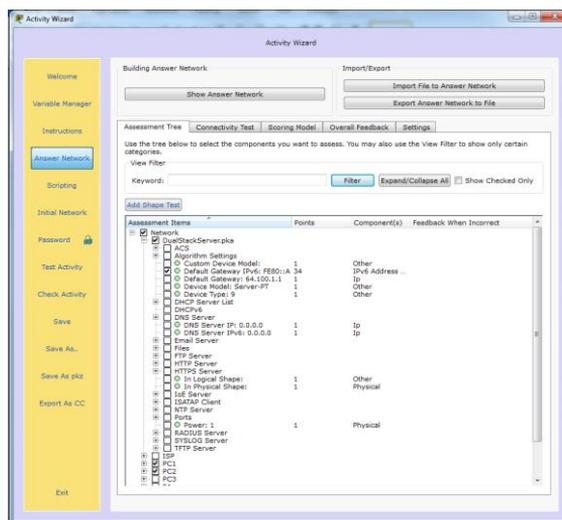
Figure 9 The Activity Wizard allows instructors to select assessment items.

Like many authoring tools, PT has a built in assessment checker (Figure 10) which allows the instructor to view what items of a given activity have been

configured successfully. This is especially useful for providing timely feedback to students.
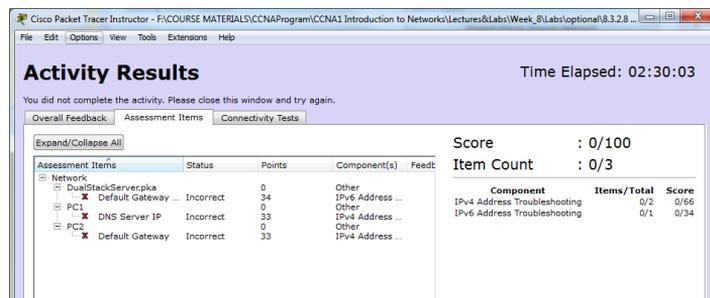

Figure 10. The Assessment checker identifies assessment items that have been either completed or not.

Each of the four CCNA modules has a capstone project that serves as a culminating academic and intellectual experience for students, covering key objectives of the unit into one project. The students are given a case study modeling a real world network. The challenge for them is to design, build, configure or do all three to model a real network in packet tracer.

Simple real world scenario: Cisco VOIP phone setup in Packet Tracer

Here we model a network for a small to medium business office setup. There are two branches that need to be connected. Each branch has several client machines and voice-over-IP (VoIP) phones that need to communicate with each other. The objective of this activity is to get the students to understand what it may look like if they were to setup a small business office and interconnect them; the configurations involved in successfully setting up the network also needs to be documented for reference. This activity also involves configuring the VoIP phones to allow for voice communication. This can really help teach the skills they will need to configure actual physical equipment when they go out into the real world.

The following diagram (Figure 11) shows that there are four (4) Cisco IP Phones connected; two phones to the Madang network and two phones to the Lae network.
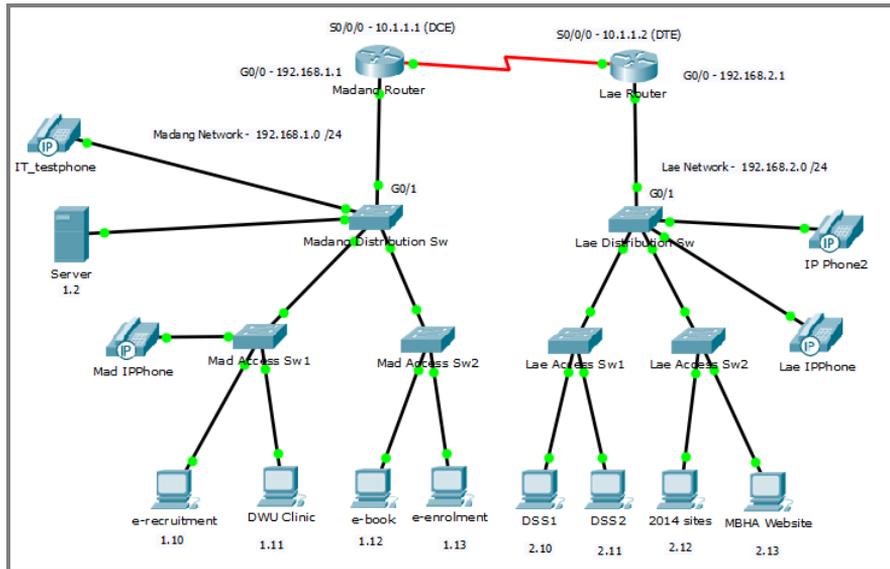
Figure 11 An overview of the small-medium business network design modelled inside Packet Tracer

To help students learn the skills of designing and configuring a network, instructions are given along with the necessary commands to use.

The current configurations for this design are shown below. The left column indicates what the student is required to do and the right column shows what commands are required to configure the device whether it be the router, switch, host personal computer (PC) or the voice-over-ip phones.

Task 1: We need to configure FastEthernet 0/0 and DHCP server on Madang router Tasks 1: Configure interface FastEthernet 0/0 and DHCP server on MadR1 (2811 router)	#Configure the FA 0/0 interface# RouterA>enable RouterA#configure terminal RouterA(config)#interface FastEthernet0/0 RouterA(config-if)#ip address 192.168.1.1 255.255.255.0 RouterA(config-if)#no shutdown
The DHCP server is needed to provide an IP address and the TFTP server location for each IP phone connected to the Madang network. After the configuration, wait a moment and check that 'Mad IPPhone' has received an IP address by placing your cursor over the phone until a	MadR1(config)#ip dhcp pool VOICE #Create DHCP pool named VOICE MadR1(dhcp-config)#network 192.168.1.0 255.255.255.0 #DHCP network 192.168.1.0 with /24 mask MadR1(dhcp-config)#default-router 192.168.1.1 #The default router IP address MadR1(dhcp-config)#option 150 ip 192.168.1.1 #Mandatory for voip configuration.

configuration summary appears.

Tasks 2: Configure the Call Manager Express telephony service on Madang Router
Tasks 2: Configure the Call Manager Express telephony service on MadR1
You must now configure the Call Manager Express telephony service on MadR1 to enable voip on your network.

MadR1(config)#telephony-service #Configuring the router for telephony services#
MadR1(config-telephony)#max-dn 3 #Define the maximum number of directory numbers#
MadR1(config-telephony)#max-ephones 5 #Define the maximum number of phones#
MadR1(config-telephony)#ip source-address 192.168.1.1 port 2000 #IP Address source#
MadR1(config-telephony)#auto assign 4 to 6 #Automatically assigning ext numbers to buttons#
MadR1(config-telephony)#auto assign 1 to 5 #Automatically assigning ext numbers to buttons#

Task 4: Configure a voice vlan on Madang Distribution Switch and the Madang Access Switch
Apply the following configuration on **MadDSw** interfaces 1 to 5. This configuration will separate voice and data traffic in different vlans on **MadDSw** switch. Data packets will be carried on the access vlan.

MadDSw(config)#interface range fa0/1 – 5 #Configure interface range#
MadDSw(config-if-range)#switchport mode access
MadDSw(config-if-range)#switchport voice vlan 1 #Define the VLAN on which voice packets will be handled#

Task 5: Configure the phone directory for Mad IPPhone
Although 'MadIP Phone' is already connected to **Madang Access Switch**, it needs additional configuration before being able to communicate. You need to configure **MadR1** CME to assign a phone number to this IP phone.

MadR1(config)#ephone-dn 1 #Defining the first directory entry#
MadR1(config-ephone-dn)#number 422 #Assign the phone number to this entry#
MadR1#config t
Enter configuration commands, one per line. End with CNTL/Z.
MadR1(config)#ephone-dn 1
MadR1(config-ephone-dn)#%LINK-3-UPDOWN: Interface ephone_dsp DN 1.1, changed state to up
MadR1(config-ephone-dn)#number 422
MadR1(config-ephone-dn)#

Task 5: Verify the configuration

Ensure that the IP Phone receives an IP Address and the phone number 422 from MadR1 (this can take a short while).

Task 6: Configure the phone directory for IT testphone

Connect IT testphone to MadDSw and power the phone ON using the power adapter (Physical tab). Login to the Madang Router and do the following configurations.

MadR1(config)#ephone-dn 2 #Defining the first directory entry# MadR1(config-ephone-dn)#number 433 #Assign the phone number to this entry#

Task 7: Verify the configuration

Ensure that the IT testphone receives an IP Address and the phone number 433 from MadR1 (this can take a short while).

Once all the tasks are completed, the student now has to verify by dialing 422 and checking if IP phone 1 correctly receives the call. The software can simulate picking up the handset to answer the call.
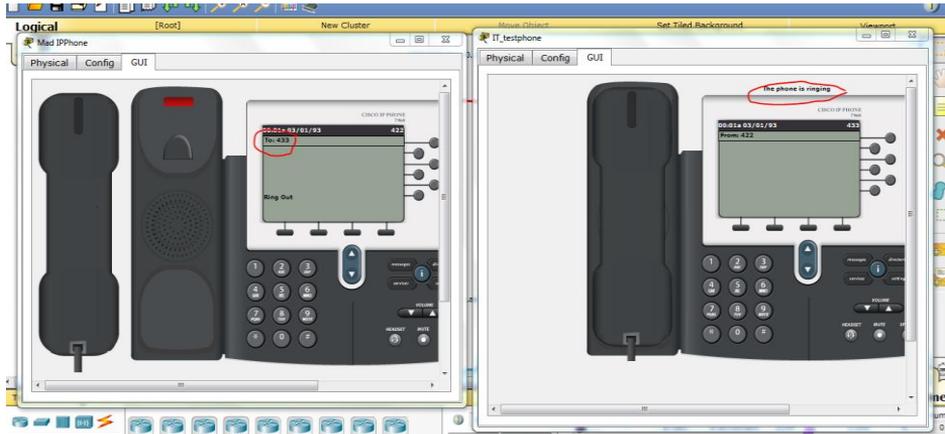
Figure 12. Once the ip phones are configured correctly, they should automatically receive dial numbers assigned.

Task 8: Repeat the same steps on the Lae network with the other two phones.
Repeating all the above steps for the Cisco IP Phones on the Lae router should connect the two phones together.

The challenge for students
The challenge for the students in this activity would be to ensure that the IP Phones on the two networks are should be able to call each other. Since both networks have a Virtual Local Area Network (VLAN) for VOICE, to connect the two voice VLANs they need to create a trunk link between MadR1 voice vlan and LaeR1 voice VLAN. Successfully connecting the two VLANs together via a trunk link will result in the phones calling each other from both networks.

Course feedback results on network academy portal

At the end of each module, students are required to complete a course feedback which in turn activates the final chapter exam. Out of several questions available, two statements were chosen to investigate students' views regarding access to equipment in the classroom compared to simulation packet tracer activities. The following graphs (Figure 14) show the feedback results from 2016 semesters 1 and 2 for each of the four modules, CCNA1 to CCNA4. The extracted figures have been drawn from different classes from 2016 regarding how they perceived the use of Packet Tracer compared with direct hardware access. Students were asked to rate how much they agree with the following statements: (a) Having access to equipment in the classroom helped me learn, (b) Packet Tracer activities helped me learn.

Rating: (1) strongly disagree, (2) disagree), (3) neither agree nor disagree, (4) agree, (5) strongly agree
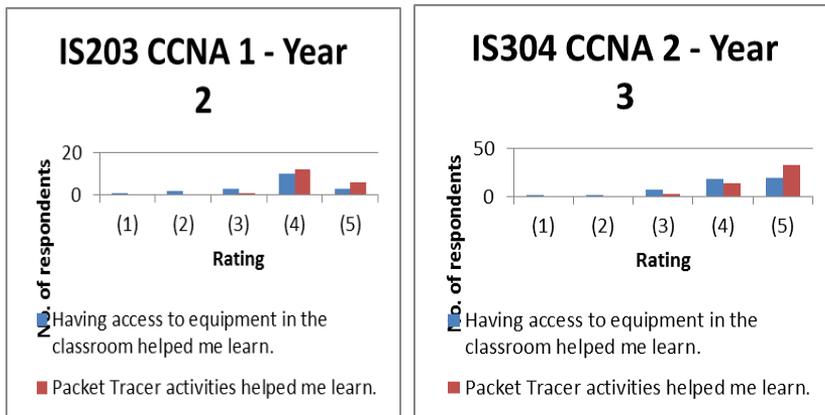
Figure 13. Graph showing the total number of respondents and their rating for the two statements in CCNA1 and CCNA2.

For CCNA 1 course feedback, 12 students agree and 6 strongly agree that Packet Tracer activities helped them learn while 1 agree and 3 strongly agree that having access to equipment in the classroom helped them learn. With CCNA 2, 14 students agree and 33 students strongly agree that Packet Tracer activities helped them.
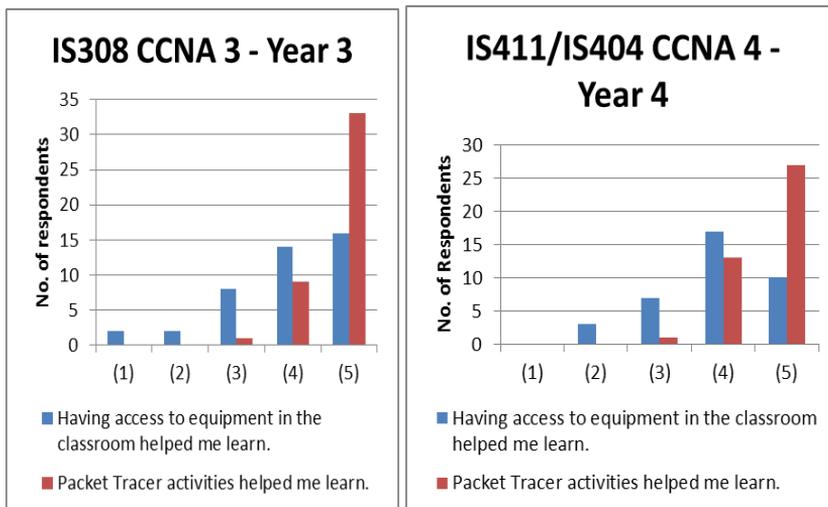
Figure 14. Illustrating the total number of respondents and their rating for the two statements in CCNA 3 and CCNA 4

As shown in Figure 14, CCNA 3, 33 students strongly agree that Packet Tracer activities helped them learn while only 16 students on the other hand strongly agree that having access to equipment helped them learn. The responses are similar in CCNA 3 and 4.

Conclusion

This paper has highlighted some challenges involved in teaching computer networks in a developing country where the demand for IT professionals continues to grow. The role of Cisco Networking Academy program to support the acquisition of ICT skills associated with computer networking, especially in underserved communities was also outlined. The program requires a cooperative undertaking between Cisco and the learning academy in ensuring that the program is fully supported and maintained.

The key features and benefits of Cisco Packet Tracer were then presented; its relevance to teaching and learning computer networks in DWU and other universities in PNG was also highlighted. The evaluations received from students clearly indicate that there is high number of students having preference over the benefits of Packet Tracer having a positive impact in their computer networks learning experience.

Whilst it can be acknowledged that Packet Tracer is not a complete substitute for hardware equipment, it allows students to practice designing, building and configuring model networks in a secure virtual environment. This "e-doing" capability is a fundamental component of learning how to configure routers and switches. Most importantly, it supports self-paced learning outside the classroom.

As Leh and Kennedy (2004) suggests, technology instruction should be made meaningful for the particular learners in PNG. Packet Tracer makes teaching and learning computer networks easier, fun and more meaningful by providing a realistic simulation and visualization environment.

Glossary

CCNA   Cisco Certified Network Associate, a program pathway in the Cisco Routing & Switching curriculum.

Computer networks   Devices that provide communication paths between electronic machines to create local networks inside buildings as well as the interconnection of networks in such structures as campuses and the Internet.

VoiP   A digital telephone service that uses the public Internet as well as private backbones instead of the traditional telephone network.

ICT   An umbrella term that includes any communication device or application, encompassing: radio, television, cellular phones, computer and network hardware and software, satellite systems and so on, as well as the various services and applications associated with them, such as videoconferencing and distance learning.

VLAN	A logical subgroup within a local area network that is created via software rather than manually moving cables in the wiring closet. It combines user stations and network devices into a single unit regardless of the physical LAN segment they are attached to and allows traffic to flow more efficiently within populations of mutual interest.

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