

Pedagogical evaluation of simulation tools usage in Network Technology Education

Woratat Makasiranondh, S. Paul Maj & David Veal

Edith Cowan University
Perth, Australia

ABSTRACT: Within the field of network technology, practical hands-on skills are highly regarded by potential employers. However, dedicated network teaching laboratories are expensive. In addition to the purchase cost, there is ongoing technical support and maintenance. An alternative approach is to provide students with a network simulator. While simulators cannot provide students with important practical skills, such as cabling and physical connectivity, they represent a useful, cost-effective adjunct to teaching programmes. This study is a preliminary analysis of two of the main network simulators currently in use.

INTRODUCTION

The ACM/IEEE computer engineering core body of knowledge includes computer networks [1]. However, many universities offer specialised, in-depth courses with instruction in excess of the ACM/IEEE guidelines. Within Australia 72% of universities are Cisco Network Academies [2] and hence offer the Cisco Network Academy Program (CNAP) curriculum. CNAP is the largest on-line curriculum in network technology [3]. Cisco Network Academies have access not only to the on-line curriculum and assessments but also to low cost equipment. Dedicated network teaching laboratories are important because they provide students with the opportunity to obtain practical, hands-on skills, which are considered important by prospective employers [4]. However, the capital costs associated with dedicated teaching laboratories are significant. Further, such laboratories require on-going technical support and maintenance. Assuming workshops consist of 20 students, each student pair should be provided with at least one router and one managed switch representing a total cost of about \$A50,000. It is possible to reduce the number of devices but this would significantly reduce student access to equipment. Ideally, such equipment should be protected by uninterruptible power supply units, be rack mounted and located in a dedicated room.

Such laboratories require on-going technical support and maintenance. The authors recommend, based on their experience, that these laboratories require at least 20 hours a week of dedicated technical support. This technical support is needed because students must be given direct access to network device operating systems. Hence, network devices need to be regularly updated and also re-imaged. Network devices are designed and constructed for conditions where networks are configured and left largely untouched for considerable periods of time. In a dedicated network teaching laboratory, depending on the number of students, cable connections to devices will occur numerous times per day. Over a period of years this results in an accelerated wear and tear of the physical devices. Hence, the useful life span is likely to be considerably reduced, and so a regular device replacement policy must also be costed.

An alternative approach is to provide students with a network simulator. While simulators cannot provide students with important practical skills, such as cabling and physical connectivity, they represent a useful, cost-effective adjunct to teaching programmes. Simulators are also of considerable importance for practising professionals seeking to obtain and upgrade their professional qualifications.

SIMULATORS

Simulation tools are useful for modelling and evaluating network protocols and traffic. Such tools are important because it is impractical to conduct experiments on a *live* network. However, many simulators are primarily research tools and their use in a teaching context may be problematic [5]. One of the main problems is these tools are complex and may be difficult to use. Students, especially novices, ideally need easy to use tools that help them develop cognitive models.

Diagrammatic model representations are considered to be particularly valuable. According to the principles of Constructivism, students must construct knowledge rather than simply being recipients of information [6]. Glaserfield states:

... knowledge cannot simply be transferred by means of words. Verbally explaining a problem does not lead to understanding, unless the concepts the listener has associated with the linguistic components of the explanation are compatible with those the explainer has in mind. Hence it is essential that the teacher has an adequate model of the conceptual network within which the student assimilates what he or she is being told. Without such a model as a basis, teaching is likely to be a hit-or-miss affair [7].

Although the usage of the highly abstraction-levelled simulation tools for learning purposes is possible, such usage requires a further creation and modification of front-end interfaces [5][8]. Without a suitable Graphical User Interface, novices are likely to experience difficulties with these research-based simulation tools.

However, these problems largely have been addressed and so network simulators represent a low-cost method of teaching network technology. A typical network simulator allows students to design and configure a network without the need for dedicated network devices. There exists a wide range of simulators that offer different degrees of functionality and flexibility. An important criterion is that the simulator must mimic, as closely as possible, actual network device operation. Two simulators commonly used in teaching were analysed as follows.

PACKET TRACER

The Cisco Network Academy recently introduced Packet Tracer - a network simulation software tool for teaching. It allows students to create network topologies and then configure the associated devices. Further, it is possible to inject packets into these networks and observe the results. This software can be deployed on a standard PC and then used by students studying from home. It is possible to configure Packet Tracer as a multi-user system. The Packet Tracer software allows students to design a network based not only on different types of devices such as routers and switches but also on specific models of devices (Figure 1). However, networks must be considered in the context of rooms and building. Packet Tracer allows users to design a network in the context of a given physical environment and, hence, develop the associated cable runs (Figure 2).

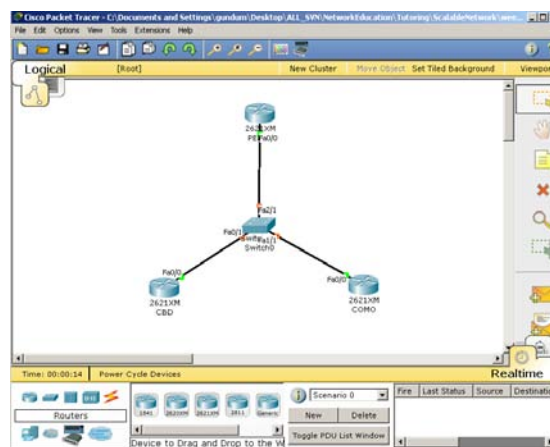


Figure 1: Packet Tracer network device topology map.

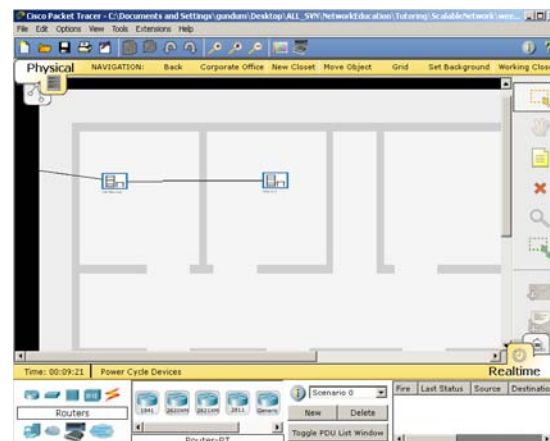


Figure 2: Packet Tracer building topology map.

EVALUATION

Both Packet Tracer and GNS3 are freely available and have comparable user interfaces. Packet Tracer and GNS3 were evaluated according to a range of criteria (Table 1). Each simulator has strengths and weaknesses - arguably there are no outstanding limitations or benefits to either tool. However, one criterion considered important by the authors is the ability to integrate the simulator with other software tools, such as Security Device Manager (SDM) and Wireshark. SDM is a graphical user interface used for configuring network devices and is progressively being deployed as an alternative to the CLI. Wireshark is a software tool that can capture and analyse data communications traffic such as Ethernet Frames and IP Packets. Both of these tools are commonly used in real networks for configuration and also fault diagnosis.

CONCLUSIONS

Practical hands-on skills are of paramount importance to network technology students. Such skills are highly regarded by prospective employers. However, to establish a 20-user network teaching laboratory with ten routers and switches costs approximately \$A50,000. In addition to this, dedicated technical support is needed for at least 20 hours a week. Further, regular use by students exacerbates equipment deterioration and equipment replacement also must be funded. Network simulators offer functionality that closely mimics a real network. Both Packet Tracer and GNS3 provide extensive functionality and hence are valuable, cost-effective teaching tools. Each tool has advantages and disadvantages. The authors recommend the deployment of Packet Tracer primarily because it is an integral part of the Cisco Network Academy Program. Experience with Packet Tracer to date suggests initial learning should be based on actual equipment. Thereafter, use of a simulator is beneficial to student learning.

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Table 1: Evaluation result of simulation tools.

Comparison Criteria	Packet Tracer	GNS3
Proprietary to equipment vendor	Proprietary to Cisco	Support Cisco IOS and JuniperOS
Legal issue	Simulated Cisco devices, no legal issue	Legal issue with obtaining IOS
Availability	Free for CNAP student only Not accessible for other students	Software is Open source; however, IOS are not provided and it is essential to run the software
Simulation level	Simulation	Emulate the behaviour of devices through IOS
Support of configuration command	only limited number of supported command	Fully support every commands, depending on version of IOS
Create a pre-define learning situation	Yes	No
Assess and compare the input configuration to the pre-define solution	Yes	No
Connection to real equipment	No	Yes
Virtual connection between different instance of simulation software	Yes, with special protocol between program instance in a different machine	Yes through multiple virtual interface of the Operating System (OS)
Physical connection between different instance of simulation software	No	Yes, through real network traffic
Physical detail of simulated devices	Provide a photographic front-panel of devices in configuration. User can modify the devices by inserting/removing an expansion module.	Doesn't provide physical detail of devices. Different devices are distinct by different version of device operating system. Doesn't concern on the different in physical level of the devices.
Location and distance information	Provide location and distance related information; depict by diagram represent places and distance.	Working in a logical interpretation only, doesn't provide any physical perspective. Only provide logical topology
Virtual level interpretation of the simulator: Cabling	Stimulate users perception of different physical connectivity by providing different cabling symbol for different connection types	Doesn't provide distinct symbols of different connection types
Type of equipment support	Router Switch Other end-devices: PC, IPPhone, TabletPC, Printer, Server	Router and Switch
Level of abstraction	Higher level of abstraction with less implementation details	Lower level of abstraction, Simulation give a higher detail by incorporate a real packet which can even be used to connect with real devices outside the simulation software

Table 1: (Continue).

Comparison Criteria	Packet Tracer	GNS3
Computation resource consumption	Consume less computer processing resource	Consume high computer processing resources, due to providing a lower implementation detail of simulation
Pedagogy features	Provide animation of traffic and details of send/receive packet within the designed models	Doesn't provide traffic information. User have to capture the traffic by other third party tools
Displaying protocol datagram in simulation (network traffic analyser)	Provide high detail of protocol datagram of the simulated traffic	Doesn't provide the ability to view the datagram to analyse the behaviour of the protocol. However, this ability can be gained from a connection to other protocol datagram analyser such as WireShark.
Interface of the text-based configuration screen	Only to the provided configuration method	Can change the configuration environment to any other real terminal software, Windows Telnet, Putty, HyperTerminal, etc.
Graphical interface configuration screen	Basic graphical user interface of configuration is built-in software	Can be able to connect to other graphical configuration interface such as Cisco Secured Device Manager (SDM)
Interface with other third party software	There is no interface with other third party software	Can be done through virtual interface
Scalable of simulation (Number of devices support)	Support unlimited number of devices, due to running in highly abstract level. Doesn't rely on the performance of the host machine.	Support only limited number of devices, which depending on the performance of the host machine.
Quality of configuration response	Suppressed configuration response, to only supported command.	Provide more detail of realistic configuration responds.
Supported operating system	Windows XP Linux	Windows MacOS X
Complexity of the tools	Simple interface, drag and drop	Intermediate; user need better knowledge on running simulation tools