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The Open Networking Lab: Hands-on Vocational Learning in Computer Networking

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The Open Networking Lab: Hands-on Vocational Learning in Computer Networking

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Abstract—**An increasingly connected society demands people who can design, set up, monitor and maintain networks of computers and devices. Traditional classroom instruction cannot keep pace with demand, and networking hardware costs can be too high for widespread classroom use. This paper presents the Open Networking Lab, a new UK initiative for supporting hands-on vocational learning in computer networking. The Open Networking Lab will facilitate the development of introductory practical networking skills without using hardware, through the provision of a web-based network simulation package integrated into learning resources and activities. These learning resources will be evaluated by students and lecturers from a cluster of Further Education colleges in the UK and will subsequently be made available to learners worldwide via free and open courseware.**

Keywords—vocational learning; further education; computer networking; network simulation.

I. INTRODUCTION

Acquiring practical network-design and network-management skills typically requires access to costly equipment, putting it out of reach of individuals and making it expensive for educational institutions. The Open Networking Lab (ONL), developed by the Open University in collaboration with Cisco, provides an alternative highly scalable solution. Within the context of a free open online course, it offers network simulation software which is accessible to learners via the web. Training need no longer be limited to the classroom, or just to those with access to expensive hardware.

The ONL will provide a complete online resource of network simulation software, activities and learning and teaching materials, which can be used to improve networking skills through virtual exploration and practice. The ONL will support learners who have little or no prior networking experience in tackling the problems typically presented by live networks, allowing them to practise and develop their skills at any time, on any computer or mobile device.

The ONL situates use of the web-based network simulation software within practical online learning activities and materials, primarily videos and screencasts. These resources can be used by colleges and other educators to deliver part of national qualifications, or by self-paced learners at home or in the work place. An experiential learning approach is used, and student activity can be monitored via learning analytics.

Upon completion, the Open Networking Lab has the potential to make a significant contribution to hands-on vocational learning in computer networking – a skill in high demand by employers – to learners with no prior experience. Learners will be able to progress from having no knowledge in this area to a level of confidence and competence.

The centrepiece of the ONL, and most innovative of its suite of resources, is the network simulator *PT Anywhere* (short for Packet Tracer Anywhere). This was developed at the Open University, as part of the European funded FORGE project. It is based on Cisco's powerful industry-standard *Packet Tracer* network simulator. Within the ONL, Packet Tracer itself is used in screencasts which explain and demonstrate key networking concepts and techniques. PT Anywhere then enables students to explore and master these within related experiential learning activities.

The remainder of this paper is organised as follows. Section II introduces Packet Tracer, and the pedagogical model on which it is based. Section III goes on to consider the PT Anywhere web-based simulation software. Section IV then discusses the Open Networking Lab itself. Section V provides a brief conclusion to the paper.

II. THE PACKET TRACER NETWORK SIMULATOR

Traditionally, skills development and knowledge acquisition in network engineering has focused on a hands-on experience using real networking equipment. The Cisco Academy programme, among others, created a compendium of curriculum-embedded labs (practical exercises) that emulated industrial experience and honed the required skills. However, a need was identified for a simulated network experience, to allow teachers to reinforce classroom learning and students to practice their developing skills. Cisco therefore developed Packet Tracer.

Packet Tracer[1] is an established pedagogical network simulation tool used by the global Cisco Networking Academy educational community [1]. With around 50,000 uses per day

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[1] https://www.netacad.com/about-networking-academy/packet-tracer

and a reach of 1,000,000 users,[2] Packet Tracer is typically used to offer students experience of a diverse range of networking protocols, networking technologies and their interactions.

Based on Scandinavian activity theory [2], Packet Tracer extends the learning experience and zone of proximal development (ZPD) of nascent network engineers [3]. It accomplishes this through simulated scenarios in which the rules regulating appropriate activity are those of real-world networking protocols and technologies. Students' apprenticeship in network-building and troubleshooting is thus mediated by the simulation tool itself. The ZPD moves from the master/apprentice in the classroom to the master/apprentice experience of the simulated scenarios presented to students via Packet Tracer, scaffolding students' development of professional and practical skills in network engineering.

Packet Tracer allows the teacher to create practical 'cognitive apprenticeship' scenarios of differing complexity, and to deliver these to their students, either in class or remotely. An affordance of Packet Tracer is its ability to model networks as well as mark as complete the practical work done by students [4], giving positive feedback and an assurance that they are progressing towards completing a set learning goal.

The pedagogical model employed extends the notion of situated learning [5]. Lave and Wenger [6] explore the space and place occupied by the student during the learning experience. By creating an instructional simulated network via Packet Tracer, the situation of learning has moved from traditional in-class participation. It has also moved the social constructivist zone of proximal development (ZPD) from the teacher/class/student in practical work to a student-centred experience with the teacher now a remote facilitator of the educational experience. Each lab created and used in Packet Tracer for student development is an individual ZPD. In social constructivist terms [7], this is described as the 'cognitive apprenticeship', the interaction between the 'master' and 'apprentice'. Packet Tracer becomes a mediator extending the experience beyond the tradition of a physical lab.

III. THE PT ANYWHERE WEB ENVIRONMENT

PT Anywhere[3] is a bespoke web interface 'on top of' Packet Tracer, sharing Packet Tracer's pedagogical model and offering a network simulation environment via a web interface. In contrast with Packet Tracer itself, which is primarily a desktop application that needs to be installed and run locally, PT Anywhere can be accessed remotely from any web browser. It can also be used as a 'widget' that can be embedded inside an online course, a Learning Management System, or an interactive eBook. Rather than replicating Packet Tracer's functionality in a web application, PT Anywhere offers its basic functionality via a minimalistic interface that can be adapted to different learning contexts and purposes.
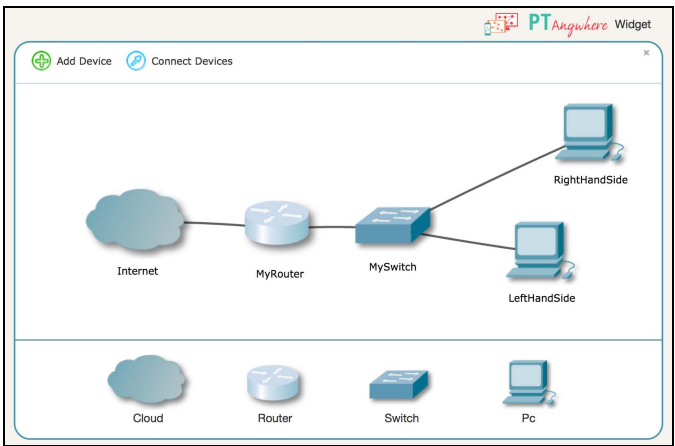
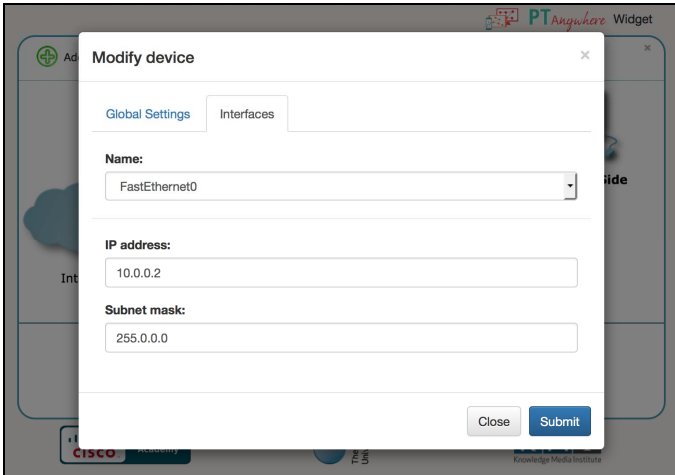Fig. 1. The PT Anywhere web interface.

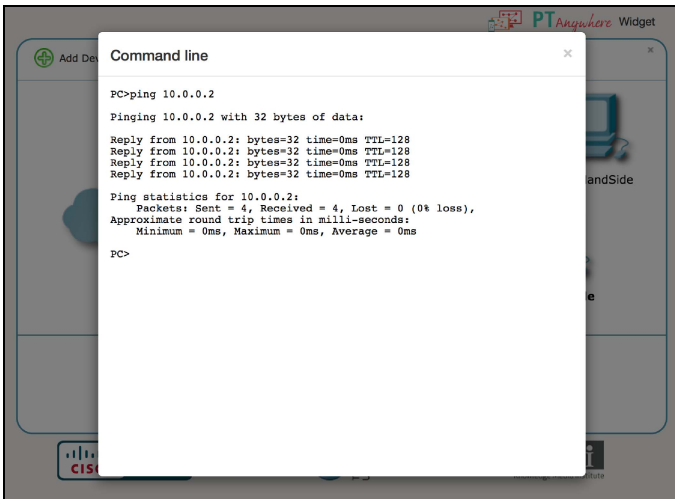Fig. 2. Modifying the settings of a device in PT Anywhere.

Fig. 3. The command line interface of PT Anywhere.

Figure 1 shows a default PT Anywhere widget interface. Learners are presented with a single router, a single switch and two personal computers. The 'Internet' in this context is a connection to the underlying remote Packet Tracer server

offering connectivity on the simulated internet. With a single router, learners can see an entire network infrastructure, to support development of a range of complex networking skills. Learners can also modify the settings of a device (as shown in Figure 2) and launch a command line interface in order to execute terminal commands (as shown in Figure 3).

PT Anywhere was originally developed in the context of the FORGE project,[4] a European initiative for online learning and experimentation via interactive learning resources. The FORGE project provided learners and educators with access to world-class experimentation facilities and high-quality learning materials via a production process [8, 9]. As part of this initiative, the Open University collaborated with the Cisco Networking Academy to produce interactive learning materials based on Packet Tracer. PT Anywhere was developed to demonstrate how learners could be introduced to basic computer networking via interactive learning resources. These learning resources included instructional video and simulation exercises, which were delivered in an eBook, as shown in Figure 4.
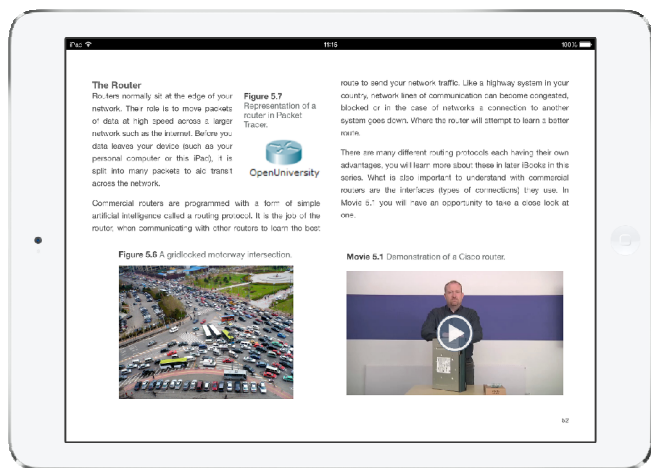

Fig. 4. Screenshot from the eBook version of the FORGE learning resources.

IV. THE OPEN NETWORKING LAB

The Open Networking Lab[5] will make available introductory practical computer networking skills training, in order to service the needs of vocational learners (Further Education and Apprenticeship levels), educators, and industry. The key objectives of this initiative are: (i) to develop and pilot world-leading, industry-based simulation software for the practical learning of computer networking on any internet-connected platform; (ii) to address the significant technical skills gap in industry by providing high quality online experiential learning resources for teaching computer networking to novice learners; (iii) to provide and promote lifelong learning resources in a key industry area, in order to help more people into skilled employment, thus addressing the significant technical skills gap in the industry.

The Open Networking Lab will further develop PT Anywhere by increasing the range of network examples offered (e.g. home networks) and by including additional learning analytics features. The learning resources developed by the project will be piloted and evaluated in partnership with vocational education providers within the UK Cisco Networking Academy. This will be followed by the publication of the developed resources through the Open University's award-winning OpenLearn open education platform.

The Open Networking Laboratory (ONL) project is divided into four key stages:

In Stage 1, the elements of the ONL are being assembled to create an online course. The study resources principally comprise: online videos and screencasts of demonstrations using Packet Tracer; modest amounts of supporting text; experiential learning activities using PT Anywhere; self-assessment questions and quizzes.

Stage 2 will see samples of the ONL resources piloted with students at a cluster of UK Further Education Colleges. During this pilot stage, the ONL will be evaluated based on feedback from college students and staff, and on data gathered from the learning analytics tools.

In Stage 3, the ONL will be revised and further developed in the light of findings from the pilot. Revisions are expected to be made to: the learning and teaching resources; PT Anywhere, and the integrated learning analytics tools.

In Stage 4, the ONL will be made openly available as a Badged Open Course on the Open University's OpenLearn platform. OpenLearn[6] offers in excess of 15,000 hours of self-study materials and receives an average of 5 million visitors per year. All OpenLearn content is completely free and accessible via any web browser. OpenLearn courses are badged, meaning that learners who complete them receive a badge that demonstrates their achievement and can be shared on social media and displayed in LinkedIn or other ePortfolio platforms.

The student's mode of study through the ONL will be firmly based on screencast demonstrations using Packet Tracer, followed by practical activities using PT Anywhere. Students will therefore benefit from the flexible, user-friendly interface provided by PT Anywhere and the realism of the underlying Packet Tracer simulation.

Figure 5 shows an extract from the ONL learning materials developed so far. This particular extract is focused on introducing the networking terms of switching and routing. Learners first watch a video demonstrating what switches and routers look like and how other network devices are physically connected to them via ports. This is followed by a practical learning activity, where learners use PT Anywhere to practice what they have learned so far.

Configuring routers and switches at the professional level is more complex than at the domestic level. Nevertheless, a simulation of a simple network enables basic principles to be established. The network shown (previously) in Figure 1 is the

PT Anywhere representation of simple internet-connected local area network similar to a home or office network. In a domestic or office context, the functions of the router and switch shown are combined in a 'broadband router'.

For the network to function properly, each component (apart from the cloud representing the 'Internet') needs to be configured. That is, each device must have various settings applied. In PT Anywhere the network is configured in the same way as real hardware would be. If this is done properly, the simulation behaves like a properly configured 'real' network. That is, data sent from one device to another will be received by the correct device.

Fig. 5. Extract from ONL learning materials featuring an instructional video and a learning activity based on PT Anywhere.

More advanced work in the ONL will involve more complex networks. These can be created in PT Anywhere by dragging devices from the bottom pane to the main display area (as shown in Figure 6), interconnecting them and configuring them. An alternative approach, used in the ONL course to scaffold student learning, is to preconfigure PT Anywhere network scenarios, so that students can be set specific tasks, such as configuring particular devices or 'troubleshooting' simple networks.

Relevant concepts and skills taught in the ONL include:

- Layer models of networks
- IP addresses, subnet masks and routing protocols
- Security
- Diagnosing and locating network malfunctions

Students' practical work to be analysed using the suite of learning analytics tools incorporated in PT Anywhere, which track the interactions of learners with the software. These tools can be used by students or teachers to review and reflect on their learning activities. The tools can also facilitate a 'coaching' style of teaching, in which student and teacher together can review the student's approach to practical work. In addition, by analysing the data collected by the analytics tools, we will be able to reflect on and draw conclusions about potential adaptations and improvements to the ONL.
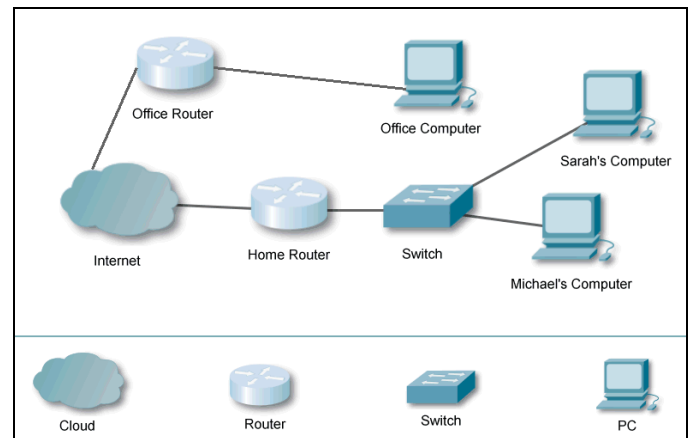

Fig. 6. A more complex network in PT Anywhere.

V. CONCLUSIONS AND NEXT STEPS

The Open Networking Lab will provide easy-to-use network simulation software, integrated into practical online learning activities and materials, primarily videos and screencasts. These resources can be used by colleges to deliver part of national qualifications, or by self-paced learners, either at home or within the work place. Following piloting and evaluation with vocational education providers within the UK Cisco Networking Academy, the free resources will be rolled out through the Open University's award-winning OpenLearn open education platform. On completion, the Open Networking Lab will make a significant contribution to addressing the global deficit in technical and digital skills.

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