

Online Learning and Experimentation via Interactive Learning Resources

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Abstract—Recent trends in online learning like Massive Open Online Courses (MOOCs) and Open Educational Resources (OERs) are changing the landscape in the education sector by allowing learners to self-regulate their learning and providing them with an abundant amount of free learning materials. This paper presents FORGE, a new European initiative for online learning and experimentation via interactive learning resources. FORGE provides learners and educators with access to world-class facilities and high quality learning materials, thus enabling them to carry out experiments on e.g. new Internet protocols. In turn, this supports constructivist and self-regulated learning approaches, through the use of interactive learning resources, such as eBooks.

Keywords—Interactive learning resources; Widgets; Open Educational Resources; Massive Open Online Courses.

I. INTRODUCTION

Higher education is currently undergoing major changes, largely driven by the availability of high quality online materials, also known as Open Educational Resources (OERs). OERs can be described as “teaching, learning and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use or repurposing by others depending on which Creative Commons license is used” [1]. The emergence of OERs has greatly facilitated online education (eLearning) through the use and sharing of open and reusable learning resources on the Web. Learners and educators can now access, download, remix, and republish a wide variety of quality learning materials available through open services provided in the cloud.

The OER initiative has recently culminated in MOOCs (Massive Open Online Courses) delivered via providers such as Udacity¹, Coursera² and edX³. MOOCs have very quickly attracted large numbers of learners; for example over 400,000

students have registered within four months in edX⁴. Also, in the four years since the Open University started making course materials freely available in Apple’s iTunes U, nearly 60 million downloads have been recorded worldwide⁵. More recently, the Open University established FutureLearn⁶ as the UK response to the emergence of MOOCs, in collaboration with premier British institutions such as the University of Cambridge.

These initiatives have led to widespread publicity and also strategic dialogue in the education sector. The consensus within education is that after the Internet-induced revolutions in communication, business, entertainment, media, amongst others, it is now the turn of universities. Exactly where this revolution will lead is not yet known but some radical predictions have been made including the end of the need for university campuses⁴, while milder future outlooks are discussing ‘blended learning’ (combination of traditional lectures with new digital interactive activities). The consensus is however that the way higher education students learn is about to change radically.

Following these trends, the European project FORGE (Forging Online Education through FIRE)⁷ is developing multimodal interactive OERs that enable online experimentation using FIRE facilities. FIRE (Future Internet Research and Experimentation)⁸ is a pan-European network of test-beds, including cloud computing services, Wi-Fi and sensor network test-beds, infrastructures for High Performance Computing, and more. FORGE is specifying development methodologies and best practices for offering open courseware and online experimentation facilities to learners, related primarily to communications and IT. As part of this initiative, FORGE is collaborating with the Cisco Networking Academy⁹

¹ <http://www.udacity.com/>

² <https://www.coursera.org/>

³ <https://www.edx.org/>

⁴ <http://www.guardian.co.uk/education/2012/nov/11/online-free-learning-end-of-university>

⁵ <http://projects.kmi.open.ac.uk/itunesu/impact/>

⁶ <http://www.futurelearn.com/>

⁷ <http://www.ict-forge.eu>

⁸ <http://cordis.europa.eu/fp7/ict/fire/>

⁹ <https://www.netacad.com/web/about-us/about-networking-academy>

in order to produce a series of interactive learning materials based on Cisco's renowned educational software for network simulations.

The remainder of this paper is organised as follows. Section 2 introduces the methodologies used by FORGE in order to develop interactive learning resources. Section 3 provides background information about the Cisco Networking Academy, while section 4 describes the use of the Cisco Networking Academy learning resources in FORGE. Sections 5 and 6 present Cisco's network simulation software and how this is being repurposed in order to be used inside the FORGE eBooks. Finally, the paper is concluded and the next steps of this work are outlined.

II. BUILDING INTERACTIVE LEARNING RESOURCES

One of the main goals of FORGE is to enable educators and learners to access and actively use online experimentation facilities in order to conduct scientific experiments. We thus follow a constructivist approach to education where learning takes place by students creating artefacts rather than assuming the passive role of a listener or reader. Our approach is based on a wide range of studies that have shown that with the right scaffolding competent learners benefit greatly from constructivist or learning-by-doing approaches [2-4]. The experiment-driven approach of FORGE contributes to fostering constructivist learning by turning learners into active scientific investigators, equipped with world-class experiment facilities.

From a learning technology perspective, FORGE is building upon new trends in online education. More specifically, in online educational platforms such as iTunes U, as well as in MOOCs (Massive Open Online Courses), such as Udacity, Coursera and edX, we see the large-scale take-up and use of rich media content. These include video in a variety of formats including webcasts and podcasts and eBooks, which can contain multimedia and interactive segments. In particular, eBooks provide a new level of interactivity since specific learning text, images and video can be closely integrated to interactive exercises¹⁰. In the context of the European project EUCLID¹¹ (EdUcational Curriculum for the usage of LInked Data), we have been producing such interactive learning resources about Linked Data and delivering them in a variety of formats, in order to be accessed from a variety of devices, both mobile (tablets and smartphones), as well as desktop computers. Building on this work, FORGE is producing interactive learning resources targeting a wide range of mediums and devices in order to maximise its impact on the eLearning community.

FORGE is enabling students to setup and run online experiments from within rich related learning content embedded as widgets inside interactive learning resources. Widgets are powerful software components that can be reused

across different learning contexts and for different educational purposes. They offer a simple interface and can accomplish a simple task, such as displaying a news feed. They can also communicate with each other and exchange data, so that they can be used together to create mashups of widgets that complement each other. The portability of widgets as bespoke apps that can be embedded into a variety of online environments ensures that the FORGE learning solutions implemented as widgets have a high reusability factor across multiple learning domains and online learning technologies. Within FORGE, widgets enable educators and learners to access and actively use online experimentation facilities as remote labs. Learners and educators can setup and run their experiments from within rich related learning content embedded as widgets inside interactive eBooks and Learning Management Systems (LMSs).

III. THE CISCO NETWORKING ACADEMY

Since 1997, Cisco Systems have established an interactive learning programme. Originally based on an in-class vocational learning experience, the Cisco Networking Academy is based on the experiential delivery of network engineering skills in-class as well as via online curriculum. Reaching an annual active student population of 1 million and with a historic reach of over 5 million, Cisco Systems present their learning programme in 170 nations through 9,000 Cisco Academies from high school to university level establishments, including less formal education institutions like prisons, charities and other non governmental organizations. The freely available courses help individuals prepare for industry-recognized certifications and entry-level information and communication technology (ICT) and computing careers in virtually every type of industry.

Currently, the primary course provided by Cisco Systems is the CCNA Routing and Switching¹². This course teaches comprehensive networking concepts and skills, from network applications to the protocols and services provided to those applications by the lower layers of the network. Students progress from basic networking to more complex enterprise and theoretical networking models later in the curriculum that is split into four modules:

- Introduction to Networking
- Routing and Switching Essentials
- Scaling Networks
- Connecting Networks

Throughout these modules, which correspond to between 8 to 11 chapters, students learn technology concepts with the support of interactive media and apply and practice this knowledge through a series of hands-on and simulated activities that reinforce learning. Each hands-on or practical activity can be delivered in situ within an educational establishment on 'live' Cisco routers and switches.

¹⁰ <http://vimeo.com/98431150>

¹¹ <http://www.euclid-project.eu>

¹² <https://www.netacad.com/web/about-us/ccna-rs>

Alternatively, the majority of practical activities can be accessed using simulation via Packet Tracer¹³, integrated since 2008 in the preceding CCNA version 4, or using remote 'live' equipment via Netlab¹⁴.

While focused on practical discipline, this study programme leverages online (web based) teaching material, covering extensive subject theory and professional practice based principles. Historically using browser based technology and recently adopting HTML5. The underlying taught content from Networking Academy can be accessed on the majority of technological platforms.

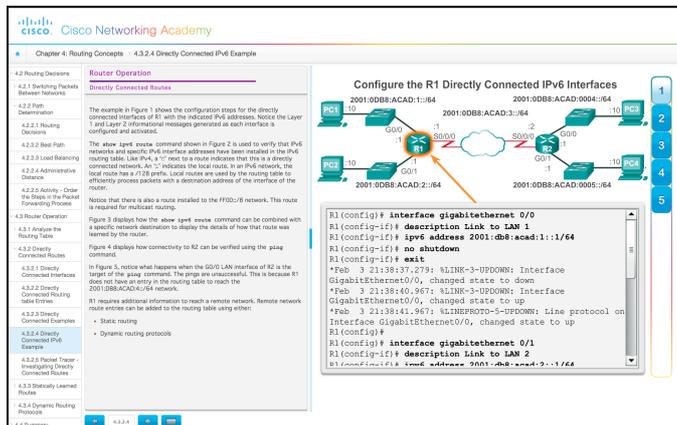


Figure 1. An example of the Cisco Academy v5 curriculum.

In 2005, the Open University (OU) introduced a scalable adaptation to the programme. Via Smith and Moss [5], the OU adapted the practical delivery model as well as extensively utilising the simulation and remote lab resources. Reaching in excess of 5000 students since inception, the programme helped in moving the traditional delivery model from in class to blended distance learning. A key element of the teaching is the reuse of the Cisco 'simulated' Packet Tracer content, incorporating this into around 50% of the continuous assessment.

IV. THE CISCO NETWORKING ACADEMY LEARNING RESOURCES IN FORGE

As outlined in the previous section, the OU is one of the partnering institutions of the Cisco Networking Academy in the UK, delivering a variety of networking courses to OU students. Building upon this partnership in the context of the FORGE project, we are developing interactive learning resources that are offered as self-study OERs to learners and educators, who wish to get a taste of what the Cisco Networking Academy has to offer. These learning resources introduce learners to the basics of network equipment and configuration, using the Packet Tracer (PT) network simulator from the Cisco Networking Academy. Within these OERs, learners can use the PT software in order to simulate different types of networks and understand how network technologies

¹³ <https://www.netacad.com/web/about-us/cisco-packet-tracer>
¹⁴ <http://www.netdevgroup.com/products/>

work and interact with each other. PT is a powerful network simulator with the ability to export network configurations and use them in real-life Cisco network equipment.

The target audience of these OERs is learners who want to gain the required qualifications towards becoming Networking Engineers. The purpose of these OERs is to teach the basics of simulated networks and the use of Cisco network equipment.

We are currently in the process of developing a widget to embed a live connection to a running instance of PT inside an iBook or LMS. This widget allows learners to experiment with simulations of various types of networks without leaving the iBook or the LMS. These simulations are presented to learners in the context of interactive exercises, thus offering reflection and self-assessment opportunities throughout the OERs. The OERs also offer a variety of instructional videos demonstrating the use of network equipment. Figure 2 shows a screenshot from the iBook version of the OERs, featuring an instructional video with a demonstration of a Cisco router.

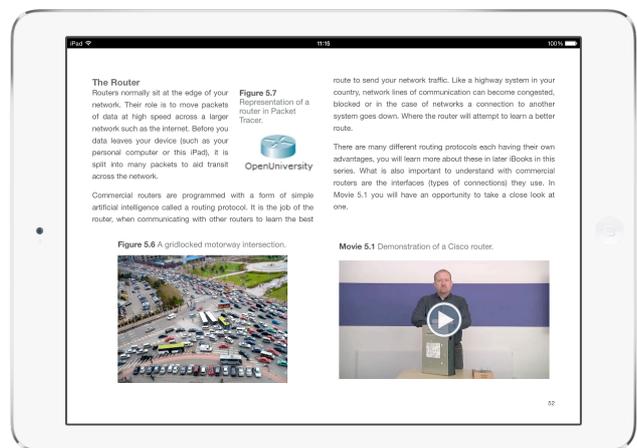


Figure 2. Extract from the iBook version of the FORGE OERs featuring an introduction to network routers and a video demonstrating a Cisco router.

V. THE PACKET TRACER SOFTWARE

Packet Tracer (PT) is a network simulator that can be used to emulate the complex routing and switching behaviours of corporate network infrastructures. Incorporating a wide range of networking protocols and technologies, users of PT are able to develop skills in utilising a variety network technologies before replicating them on live systems. Currently on v6.1, each release incorporates new protocols and technologies used by industry.

Using a user interface based on game theory [6], the design principles behind PT are based on extending the Scandinavian Activity Theory (AT) approach [7] to Vygotsky's cognitive apprenticeship [8, 9]. PT in the context of AT, acts as the mediating artefact and allowing the subject (the user in AT terms) to create free form network environments via the creation of complex scenarios (called activities in PT and objects in AT) while supporting remote interaction between

different users (in terms of rules, community and division of labour within the AT paradigm).

Based on research from Frezzo, PT is incorporated into versions 4¹⁵ and 5¹⁶ of the networking academy teaching content as well as their continual assessment. Students can study theory then apply this via practice on a range of expert authored networking activities. A form a pedagogical practice based reinforcement of theory.

In more complex scenarios, students can be given challenges to complete either against the clock or other ‘competing’ participants. Cisco annually host the Netriders¹⁷ competition and PT is often in international skills competitions¹⁸. The Packet Tracer Multi-user Protocol (PTMP), used to connect the API to external calls. Is also used in remote activities, connecting students in one:one, one:many and many:many scenarios. Smith [10] explored the potential interoperable nature of PT and investigated how large scale multi-user simulated networking scenarios could be implemented. Nominally indicated as a simulated Internet on the Internet.

Providing the basis for the widget, Figure 3 represents an underlying system with ‘simple’ PT clients connecting to a core ‘more complex’ system. Users of the simulation are able to engage with local and remote practical activities on a simulated network, using many networking native technologies within this simulated environment.

An essential feature of the PTMP framework is that it ‘does not’ send real traffic. Assuring integrity with the supporting system. Users of the PT simulated network cannot directly engage with the underlying system via the PTMP protocol, which is designed to send XML based ‘summaries’ of the interconnected PT instances.

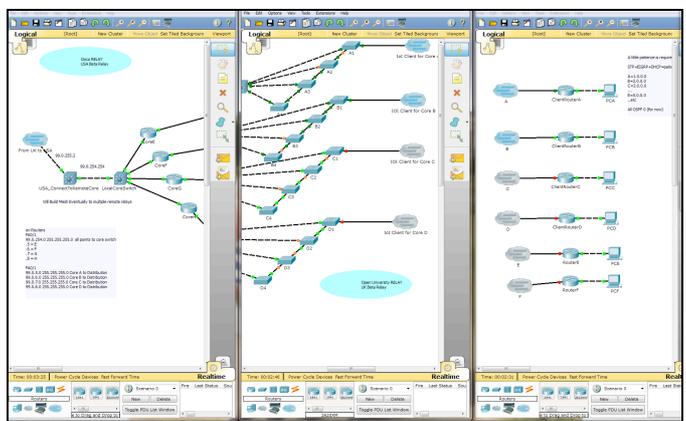


Figure 3. Example of PT multiuser USA↔UK scenario.

Network and device configurations in PT, can be copied via a ASCII/Unicode text editor into a live system. Presenting

¹⁵ <https://www.netacad.com/web/about-us/ccna-exploration>

¹⁶ <https://www.netacad.com/web/about-us/ccna-rs>

¹⁷ <http://www.academynetriders.com/index.php>

¹⁸ <http://blogs.cisco.com/csr/netacad-students-win-2-of-3-medals-in-worldskills-competition-for-networking-administration>

students and with the opportunity to practice skills in a pedagogical sandbox, experiencing ‘safe’ experimentation before applying the resulting network infrastructure. PT activities can be either locked down, restricting the experimental scope of the student, or left open enabling educational exploration. Combining both, presents a range of challenge activities, where students have to navigate networks where they do not have total control, simulating real systems and realistic behaviours. In this context, DiCerbo et al [11, 12] have established how the simulation presents a realistic alternative to the traditional practical experience on live equipment.

VI. THE PACKET TRACER WIDGET

Section 4 outlined the goal of creating a widget embedded in an iBook in order to allow students to see and try out networking concepts directly at the point where they are introduced. The creation of such a widget poses a number of technical challenges. In particular:

1. Interactive elements in iBooks are written in HTML5 and JavaScript¹⁹; no other programming languages are permitted by Apple.
2. The PT interface is designed for a point-and-click interface, as found on desktop and laptop machines. A major audience for iBook readers - perhaps *the* major audience - is via a touch interface on a tablet. Interface actions, such as drag and drop, which are easy on a laptop, do not translate well to touchscreens.

Rather than implement a full Packet Tracer Multi-user Protocol (PTMP) client in JavaScript, we chose to make use of the existing Java PTMP libraries provided alongside PT. These libraries implement a set of classes corresponding to the main concepts in PT: Network, Device, Link, and so on, allowing a Java application to communicate with a running instance of PT, query its current status (current displayed network configuration, etc.), make changes, start and stop simulations and query simulated network behaviour.

Because of requirement 1, we cannot run any Java applications within the iBook. We must therefore provide a way for the iBook widget to communicate with a Java application remotely. Figure 4 shows the architecture chosen for the widget. PT is running in multi-user mode on a (Windows) server privately hosted at the Open University, and communicates with a Web Service Bridge (implemented in Java) on a public server (also at the OU). The WS Bridge provides a RESTful API [13] exposing certain functionality of PT, with which the iBook widget can communicate. Because the RESTful API functions purely over HTTP, and JavaScript certainly supports HTTP communication, it is straightforward to implement this communication within the widget.

¹⁹ <http://help.apple.com/ibooksauthor/mac/#/blsc7344d77>

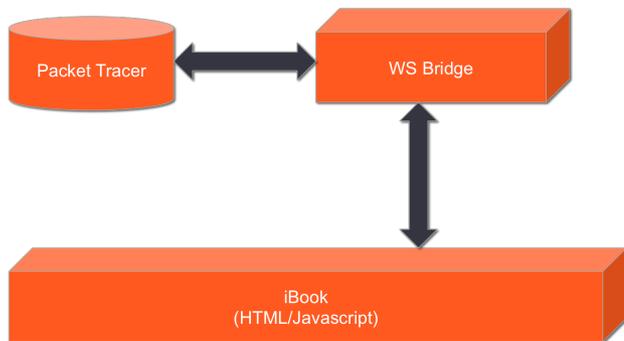


Figure 4. The PT widget architecture.

Performing an HTTP GET request on the URL of any deployment of the WS Bridge will return a JSON structure representing the currently-displayed network in PT's workspace, as a list of devices and links (where links are represented as pairs of device identifiers), each of which has metadata such as identifiers, labels, and so on. The "group" field identifies device types; currently, for simplicity, no distinction is drawn between types of network link (copper, coaxial, etc.), but the format allows easy addition of this when necessary. Each device may have multiple interfaces: a network link between two devices is in fact a link between two of the interfaces of those devices.

The creation and deletion of network devices, and the modification of device configuration, can all be achieved by sending an HTTP POST request to the deployed API URL with the appropriate JSON payload.

The operations (and required parameters, in parentheses) supported via POST are, at the time of writing:

- Create device of a specified type (devicename, devicetype)
- Delete a device by identifier (deletedevice)
- Configure a device's named interface IP settings (deviceid, interfacename, ipaddress, subnetmask, defaultgateway)
- Create a link between named interfaces of two devices (linksource, linksourceinterface, linktarget, linktargetinterface)
- Delete a link from a device's named interface (deletelinkdevice, deletelinkinterface)

In order to meet requirement 2, the interface, implemented entirely within the widget, does not attempt to replicate the existing PT user interface, but instead presents a simplified interface, appropriately adapted for touchscreen interfaces.

The widget, with a default example network configured, is shown in Figure 5. The main pane displays the example network, and the row of icons underneath allows users to choose different types of device in order to create new devices. Of course, PT supports a wide range of different types of simulated hardware; the range of options available in

the widget is restricted to generic types relevant to the material being taught. Tapping any one of these icons brings up a dialog box allowing the new device instance to be named.

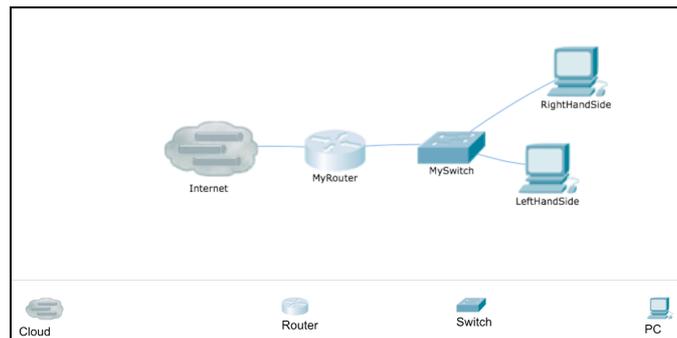


Figure 5. The PT widget interface.

The rest of the possible interactions in the widget arise from tapping on a device in the main pane. Doing so brings up a dialog box as shown in Figure 6. The range of available actions is currently small enough to be accommodated by a single dialog box. More complex scenarios are likely to require more compact nesting of options. However, it is also likely for pedagogical reasons that different instances of the widget (occurring at different points within the iBook) will provide different choices of action to the student, and later exercises may well benefit from having the more "basic" options hidden. The first drop-down menu allows the student to choose between all of the interfaces of the selected device which are linked to some other interface, in order that links may be deleted, and the second drop-down menu offers a list of available device-interface pairs to which the currently selected device and interface may be linked, in order to create new links.

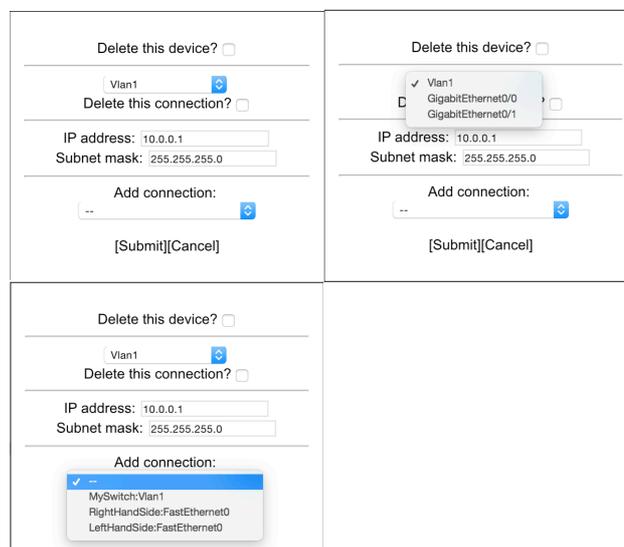


Figure 6. Device configuration dialog and options for link selection.

The widget may be inserted at any point within the iBook relevant to the text, for example as part of a learning activity. Figure 7 shows such a learning activity. Simply tapping on the image for "Interactive 5.2" brings up the widget.

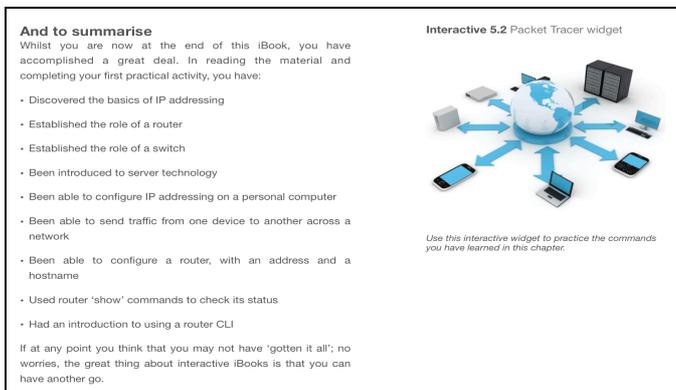


Figure 7. Launching the PT widget from within an iBook.

VII. CONCLUSIONS AND FURTHER WORK

FORGE aims at complementing online learning initiatives with laboratory courses for an in-depth and hands-on educational experience. Within FORGE, our constructivist approach is based upon the notion of the experiment. FORGE allows students to create and conduct experiments using interactive learning resources within a comprehensive learning context. In order to achieve this, FORGE has established a partnership with the Cisco Networking Academy and is producing together interactive learning materials based on the Packet Tracer educational software.

The next steps of this work involve the further development of the Packet Tracer widget in order to allow different types of learning activities and experiments to be conducted by the learner. Understanding how learners and educators use the FORGE learning resources is also our next goal. Towards this goal, existing and commonly deployed quantitative and qualitative evaluation methods, such as questionnaires and surveys with educators and learners, as well as Learning Analytics methodologies will be adapted and augmented. The collected quantitative and qualitative data will be analysed in order to meet specific requirements for evaluating the use of our learning resources, as well as their potential impact on self-regulated learning.

VIII. ACKNOWLEDGMENTS

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