Multiuser Collaborative Practical Learning using Packet Tracer

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Abstract— To support the delivery of group-based remote collaborative work in the practice based learning domain of computer networking. Historically this has presented challenges in scale, management, security and technological resource to support delivery, assessment and learning. In partnership with the packet tracer development team at Cisco Systems, this paper explores the pedagogical and technological potential for a worldwide 'simulated' Internet and reports on initial research.

Keywords- packet tracer; practice based; collaborative; cisco; remote learning; virtual labs; Networking Academy; CCNA; Supported Open Learning.

I. INTRODUCTION

The Open University in the UK commenced offering the Cisco Academy Programme, CCNA, in 2005 as a blended distance-learning course as part of the Foundation Degree in ICT. In the four years since inception this course has reached an excess of 2500 students across the UK and some internationally all taking the course in the blended distance-learning mode.

A challenge, which persists, is managing access to router and switch technology, offering students an opportunity to engage in interactive practical activities, therefore giving a view of the complexity involved in network environments such as a corporate WAN infrastructure or the Internet.

The course team responsible for the management of delivery explored a range of tools, including Netlab+ distributed by NDG [1] and Packet Tracer (Cisco Systems inc). This included setting a range of assessment tasks using these tools and experimenting in group based delivery of remote teaching in Cisco Networking, as researched by Smith and Moss [2] along with Prieto-Blázquez [3] in the setting of course assessment items and the management of synchronous and asynchronous learning using both resources.

With the advent of multiuser functionality in Packet Tracer 5.0 and the development of the Packet Tracer Multiuser Protocol [4], The Packet Tracer application enables students in disparate locations to interact on a common simulated practical activity. Potentially leading to an understanding of the practical and underpinning principles of complex computer network environments.

A. *The mechanics of Packet Tracer*

As a simulation environment, Packet Tracer offers router, switch, server, work-station and protocol functionality for students and educators to create diverse and complex routed scenarios, extending the pedagogical and practical experience during participation in the Cisco Academy programme.

The Cisco CCNA version 4.x Exploration and Discovery curriculum contains embedded lab exercises for the students to complete. These are either in class on live technology, or remotely via the Netlab+ system. Otherwise labs exist, launching the Packet Tracer application from within the Cisco curriculum content.

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When launched the Packet Tracer activity is goal-based, giving students milestones and rewards, indicating completion percentage based on the activity scenario.

As a simulation tool, the 'network operating system' deployed on the included devices is a subset of the real-world equivalent, having the same behavior, performance and idiosyncrasies within a contained experience.

The multiuser functionality allows students and academic centres to create environments that can interact, irrespective of locale and supporting academic environment. Figure 1 illustrates two independent instances of Packet Tracer using a peered network connection, with two simulated workstations exchanging ICMP network traffic.

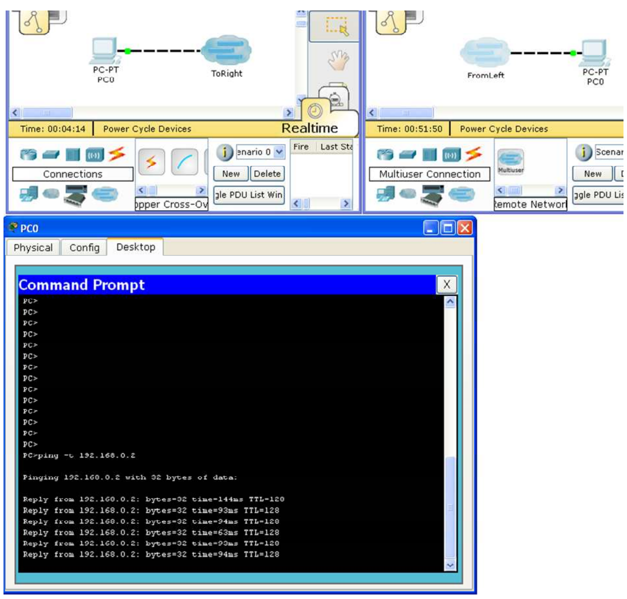

Figure 1. Peered example of Packet Tracer Multiuser communication.

A multiuser connection can be established on any port, with ports 38000 to 38999 presented by default. An academic centre may elect to use an alternate port according to local security policies.

Packet Tracer is therefore able to handle multiple multiuser connections between multitudes of users, with one:one, one:many and many:many remote or local collaboration scenarios available to students and academic centres.

Designed to be 'easy to use', any student or academic using Packet Tracer can quickly create a multiuser connection by using the default port, and an IP Address or domain name as illustrated in figure 2.

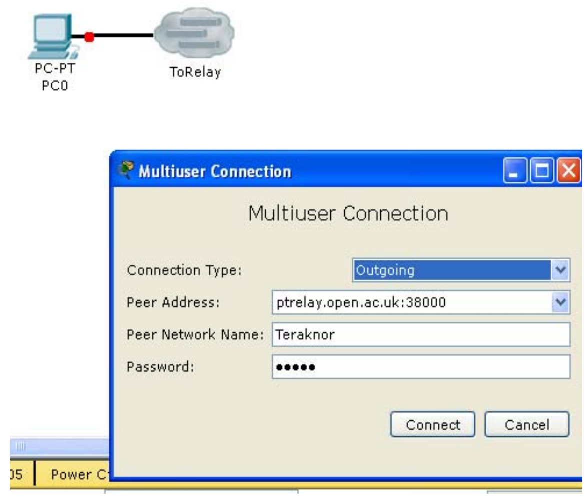

Figure 2. Creating a multiuser connection from Packet Tracer

With the many:many multiuser interconnection available, multiple academic centres may create a mesh, with students interconnecting to a collaborative environment internally or externally to the system and complete an extensive range of practice based learning activities.

II. Security and Trust Issues

Against the pedagogical benefit of creating a tool, designed to allow students and academic centres to connect across a LAN, WAN or the Internet via Packet Tracer and engage in learning activites. The application also creates a trust issue in the explicit exchange of IP address or domain information.

Any one:one connection between peers would infer an implied trust, ensuring that both parties are aware of the others need to connect, each party will be present at the workstation hosting the packet tracer application to permit or deny the initiated connection.

With a one:many, in an internal scenario, the same trust principle as the one:one connection relationship is implied. The academic leading the practice-based session will be present to invoke the activity and therefore trust any incoming connections.

At the stage where centre-to-centre communication takes place and communication has to interact with an academic organization's security policies and firewalls. A question is raised regarding the authenticity of the remote connection and the trust surrounding whom the connection may be coming from. The complexity of the question increases with each new connection and potential participant.

Furthermore, when a remote-learning scenario occurs, with students who study via blended distance learning, the likelihood is the students have never met and therefore have not formed an albeit basic trust relationship, summarized by the need for social exchange to engender trust, Xueming [5]. This raises an immediate issue, insomuch as the students are now expected to exchange IP address, port or domain information for a direct communication with someone whom they have no personal contact with or no form of comeback.

Therefore, in the establishment and creation of a one:one connection between distance-based students (in respect of figure 2), who may have never met and therefore have a less personal trust. The potential for abuse, via hacking, exploit, denial of service or cyber stalking is apparent and would present many academic centres with multiple liabilities.

III. THE RELAY SERVER

Resolution of the security threat is essential and maintaining trust between distance-based students and remote centres of paramount importance.

In exploring potential solutions research focused on the many:many property of Packet Tracer. With the question: "what if an intermediary was available?"

With a many:many scenario, trusted secure devices could be created for academic centres as well as students to interconnect. Now the trust is with the intermediary, the domain and the port of the intermediary is known to everyone. No individual or academic entity would exchange with any other individual or academic entity any sensitive information regarding network address, local domain or port.

Fig 3, gives an exemplar scenario, with relay servers hosting Packet Tracer, each server acting as a trusted intermediary. Each system would be secured in reasonable technological terms and have external defense within their local infrastructure.

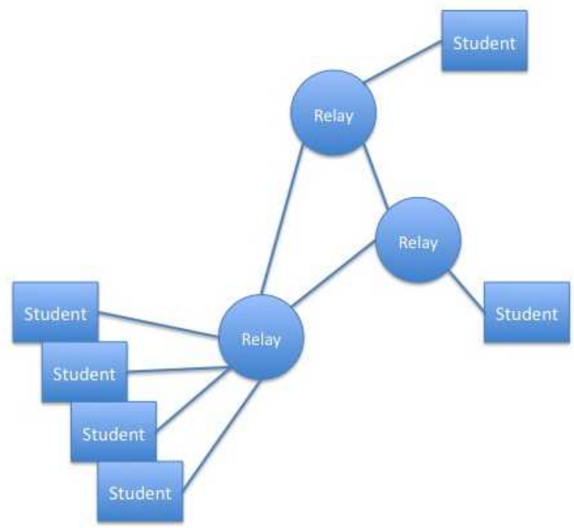

Figure 3. A mesh of intermediary relay servers

Packet Tracer exchanges PTMP traffic in any remote communication, the protocol makeup (Table 1) does not exchange originator identifiers, only the last hop. Therefore with PTMP acting as a wrapper protocol, Packet Tracer exchanges the simulated network infrastructure protocol information, not external (real world) information.

TABLE I. PTMP PROTOCOL STRUCTURE

PTMP Protocol Data
PTMP Wrapper
TCP Datagram
IP Packet

The outcome for using an intermediary, as a relay server is the absence of information exchanged at a 'human' level as well as at 'machine' level, between the distance-learning collaborators. Therefore trust is implicit, based on the neutrality of each relay server in the learning exchange.

For academic centres and individual learners, the challenge remains to agree on a collaborative learning activity and the pedagogical engagement methodology.

IV. CREATING AN INTERNET ON THE INTERNET

Relying on one intermediary relay server limits the potential value in scale and reach of the collaborative opportunity available. The sole purpose of Packet Tracer is to engender understanding of complex network topologies and the interaction of protocols and devices in this environment.

The multiuser feature, supported by the formation of a collaborative interlinked mesh of intermediary relay servers, the system gains resilience and localization, with the potential for a worldwide 'ring' of systems all interconnecting each accommodating locale specific preferences and academic requirement.

The practical outcome of such a mesh is the immediate advantage in offering academic centres and individual learners with a system, able to provide them with the learning experience of building a complex internetwork without the political and security complexities of using the 'real' Internet.

Packet Tracer provides access to inaccessible IPv4 and IPv6 address ranges, DHCP, NAT, STP, VPN, QoS, OSPF, EIGRP, RIP, dot1q, VTP, etc. in an environment allowing students to make mistakes and learn from their experiences.

V. PEDAGOGICAL BENEFIT

In a collaborative distance-based system, the creation of an intermediary relay supported mesh of relay servers; Laurillard [6] identified how academic centres as well as students can engage in distance-based synchronous and asynchronous learning. The use of Packet Tracer in this context supports these findings and meets the local technological and conceptual needs of the students at the time of interaction.

The flexible nature of Packet Tracer precludes, with suitable core topology design, more than one group of learners can interact with the system at the same time independent of other learning collaborations.

Assessment-based learning may take place using the local Packet Tracer client in the activity mode, with students interacting in a 'staged' learning and problem-solving scenario therefore providing discovery based exploratory learning.

Having a constructivist ethos, the Packet Tracer environment is open to the personal interpretation of the student as well as the guiding academic is synonymous with Piaget [7]. The distributed learning methodology supported by Packet Tracer, with the multiple sources of information, each giving form in a constructivist paradigm is gives credence to the emergent concept of connectivisim from Landauer and Dumais [8]

Along with the distance based asynchronous and synchronous learning, collaboration can co-exist between classes of students in a specific geographic locale as well as internationally.

VI. BUILDING THE TECHNOLOGY

The Cisco Academy programme having a diverse academic community represents students and academies from a range of academic and educational environments. The essence is to create an intermediary relay open to replication in locations where technology is at a premium, as well as for institutions able to host complex resources to support others.

Four technology models, each able to interact with the other have been designed:

- Model 1: a single server core, using a router-on-a-stick methodology.
- Model 2: multiple cores in a hub-and-spoke mesh, all connecting to a central unseen hub residing on a higher specification single server.

- Model 3: multiple cores in a hub and spoke mesh, all connecting to a central unseen hub. Each core residing on one of five lower specification servers connected in a local or distributed cluster.

- Model 4: multiple cores in a hub and spoke mesh, all connecting to a central unseen hub. Each core residing on a higher specification single server using VM Ware ESXi server to separate the server instances.

Each model offers differing benefits, in teaching scenario and technical deployment, and the need for adaptation to local academic and technical need, must be central to design.

To summarize the anticipated needs, each design is focused on creating a range of systems to:

- Simulate protocol behavior on range of protocols
- Explore alternative simulated security settings
- Offer alternate levels of complexity
- Explore different addressing schemes and infrastructure behaviors

- Engage students in different practice-based learning experiences

Students and academic centres have the freedom to create their own Packet Tracer clients and interact with the intermediary servers as they wish. In an experimental context, a default client has been provided to ensure access and a common entry point into the multiuser environment.

Support has been given to the research by the Cisco Systems Packet Tracer development team in developing an add-in (using the PTMP external applications feature).

The multiuser connection manager (MUCM) is an essential tool that manages redundant connections as seen in figure 4. Otherwise when a multiuser participant leaves any peered packet tracer connection; the partner user has to delete the peered connection.

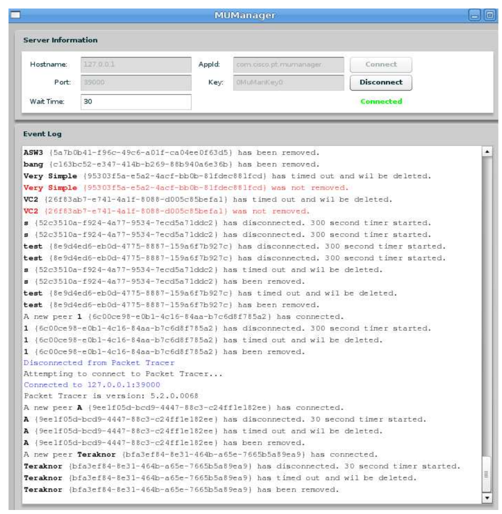

Figure 4. Multiuser Connection Manager

In building the server for the test case, a common distribution of Linux has been deployed.

VII. INTIAL RESEARCH AND FINDINGS

The research programme has commenced with Model 1, during August/September 2009. With Distance learning students participating from the UK Open Universities T216 (Cisco Networking/CCNA) and T824 (Advanced Networking/CCNP-BSCI) courses, along with volunteers from the Cisco Learning Institutes Networking Research Collaborative.

The test scenario was for each participant to connect to the relay server via two clients (both on the same local host), make an EIGRP peering by adding a new network into the autonomous system routing process for each client, add at least one workstation at each, ping the default gateway, then finally ping each other, all within the packet tracer environment.

Testing was confined to a three hour window from 17:00 to 20:00 GMT.

During this time over forty participants joined with a peak of 15-20 different peers in the 19:20 to 19:40 window.

To ensure minimum behavior, one host ran a continuous simulated client-to-client ping and a continuous simulated ping to the intermediary server.

The MUCM managed to rollback connections, ensuring deletion when disconnection notice expired after five minutes.

At 19:40 (estimated) the Packet Tracer application crashed, during a period of apparent peak activity, the research team; are revisiting the test case by examining four scenarios in a controlled test environment.

- Emulating the same event, increasing load, to observe the factors leading to failure.
- Testing the system on Linux without MUCM interactivity.

- Testing the system with MUCM in Windows
- Testing the system without MUCM in Windows.

And with all of the scenarios, upon failure repeating the test without EIGRP present, early findings have concluded that the 15-second hello time for EIGRP works within a LAN-based multiuser setting. As soon as Internet communication is in play, the application, operating system, TCP/IP stack and transmission latency all combined end to end, precludes that the next expected hello-packet arrives too late for the simulator. Incurring a hold down and increased application activity.

VIII. CONCLUSION

The test case has already proven the potential for disparate individuals from diverse locations to connect and engage in a semi-synchronous, primarily asynchronous practical activity.

Following a simple practical scenario, each participant completed the tasks set. Therefore, supporting the development of group based participatory activities in the sphere of situated learning [9] in an online environment.

There is scope for further development of Packet Tracer along with research and analysis of the pedagogical benefit for students and academic centres. It can be surmised that the first stage of the research has shown how the eventual creation of a mesh of packet tracer relay servers could be developed for the purpose of enabling students worldwide engage in the creation and interaction with an ‘internet on the internet’.

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