Scientific Research and Essays Vol. 6(1), pp. 168-174, 4 January, 2011
Available online at http://www.academicjournals.org/SRE
DOI: 10.5897/SRE10.962
ISSN 1992-2248 ©2011 Academic Journals

Full Length Research Paper

Low cost, pedagogically enhanced, remote access, laboratory based instruction for developing countries

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Accepted 10 December, 2010

Practical, hands-on skills are of paramount importance to potential employers. In the field of network technology students must be able to configure, manage and fault diagnose networks. The world's largest supplier of network equipment established the Cisco Network Academy Program (CNAP). Institutions qualifying to become CNAP academies can purchase low cost network equipment. However, for many institutions this may still be prohibitively expensive. One solution is for institutions in developing countries to remotely access network teaching equipment in developed countries. This is potentially a cost effective solution if institutions are in different time zones. This paper demonstrates a cost-effective, pedagogically enhanced instructional platform for remote access students.

Key words: Cisco Network Academy Program (CNAP), packet tracer, network education, remote laboratories, State model diagrams.

INTRODUCTION

The Internet is now an integral part of commerce and industry. Participation in the global economy depends upon the Internet and hence an appropriately trained workforce in network technology. Technical education is being seen in countries around the world as an important contributor to the creation of a 21st century workforce. An important component to learning is the use of hands-on activities (DiCerbo, 2009).

Whilst employment opportunities are often cyclical it is recognized that there is a global shortage of suitably qualified information technology (IT) staff. It has been noted that:

> The skills vary from low level, computer literacy skills needed by individual members of society to access services to high level technology skills needed by specialist ICT professionals (Alexander, 2009).

This problem is exacerbated by factors that include:

* Equipment costs.
* Rapid changes in technology.
*Decreasing enrolments in information.
*Communication Technology (ICT) courses.

In order to alleviate ICT skills shortages, countries such as South Africa have employed a range of strategies that include educational reforms and investment in education. The importance of ICT is such that a dedicated South African ICT university has been proposed (Alexander et al., 2009).

MATERIALS AND METHODS

The Cisco Network Academy Program (CNAP) is a global ICT education program. CNAP provide not only online curriculum and assessment but also software tools and low cost network equipment. The courses are designed to prepare for both entry level employment and also on-going professional certification. Accordingly, there are a number of different courses that include:

- IT essentials.
- Cisco Certified Network Associate (CCNA)
- Cisco Certified Network Professional (CCNP).
- Security.

CNAP is offered in 162 countries and to over 900,000 students. It is the most widely used network curriculum and the international standard by which professional competency in this field can be measured.

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CNAP offer low cost network equipment that is an integral part of the different courses. There are four courses in the CCNA curriculum namely:

1. Network fundamentals.
2. Routing protocols and concepts.
3. LAN switching and wireless.
4. Accessing the WAN.

The minimum equipment needed to implement the different topologies that are an integral part of all this course courses is as follows:

- Three Cisco 1841 routers with Base IP IOS.
- Three 2960 switches.
- Two Linksys wireless routers.

However, in addition to this additional laboratory equipment is needed that includes:

- One PC to act as application server.
- Two desktop PCs to act as clients.
- NIC cards for all three PCs.
- Two wireless LAN adapters for client PCs.
- Ethernet and serial cables.
- Cable making and testing equipment.
- Standard 19 inch equipment rack.

Within Australia this equipment would cost approximately AUS$2,500. However, to improve the student equipment ratio sets, equipment are needed. The problem is the cost that rapidly escalates. Ten years ago two dedicated network laboratory were commissioned at this university at a cost of approximately AUS$300,000. In addition to this, dedicated technical support is needed to maintain the equipment. Furthermore, there must be a replacement policy with associated funding implications. Experience to date suggests the equipment should be replaced on a 5 to 8 year cycle.

RESULTS

The CNAP curriculum was therefore evaluated. There are over 11,000 CNAP academies worldwide. In some countries CNAP is an integral part of their national academic standardized programs (Revzina and Grakovski, 2009). Approximately, one third of Australian universities are CNAP academies. Accordingly, many institutions have invested heavily in network teaching equipment.

The use of remote laboratories is well established in other engineering disciplines (Kutlu and Tasdelen, 2010). This is important especially for remote, on-line students. However, even when provisioning for remote students is taken into account this equipment is typically only used for part of each working day and only during the teaching semesters. In this multi-mode access environment equipment reservation and scheduling is important (Toderick et al., 2005). Institutions have different policies but at this university open access by students to dedicate network teaching laboratories is not permitted. This helps reduce maintenance costs.

Various network simulation tools are freely available such as the CNAP packet tracer. Packet tracer is considered an integral part of the CNAP curriculum and allows students to experiment with virtual networks. Using this tool, student can build, configure and test a simulated network. Usefully packet tracer offers both logical network topology (Figure 1) and a physical view (Figure 2).

This is important because for novice learners conceptual understanding typically is based on experience of the concrete. It has been demonstrated that packet tracer can be used for both instructional and assessment purposes (Frezzo et al., 2009).

However, it has been noted that whilst on-line students are popular and cost effective method of offering curriculum research has shown that students did not want to take all their laboratory workshops on-line (Lawson and Stackpole, 2006). More significantly, CNAP emphasize that a simulator is a useful teaching and learning tool but not a replacement for actual hands on workshops. Potential employers require students to have practical, hands-on skills – something can only be taught in workshops where students work with the actual devices.

The problem is therefore to provide students with equipment. The following are cost effective alternatives for institutions with limited budgets. A low cost multi-functional networking device is available – the Cisco unified communications 500 series model 540 for small businesses. This is a relatively affordable device that provides: voice, data, voicemail, video, security and wireless capability. This device includes the following built-in interfaces:

- Eight 10/100 Mbps LAN.
- One 10/100 WAN uplink.
- One 10/100 Ethernet expansion port.
- Eight Power over Ethernet ports.
- Four FXO or two BRI ports.
- WLAN interface.

This device modular and hence can easily be upgraded. An alternative solution is the purchase and use of second hand equipment. This equipment is readily available on the Internet. However, it may be problematic to obtain a class set and reliability may be an issue. The authors recommend, based on their experience, that institutions purchase more second hand equipment than actually needed. This allows for replacement of failed devices and also the option to cannibalize for spare parts.

Remote access to another institution's equipment is another option. As indicated above many institutions have invested heavily in dedicated network teaching laboratories that are only fractionally used. Remote access is typically by means of the text based command line interface (CLI). However it has been demonstrated that the CLI is verbose, difficult to use and is not conducive to higher order learning. In order to address

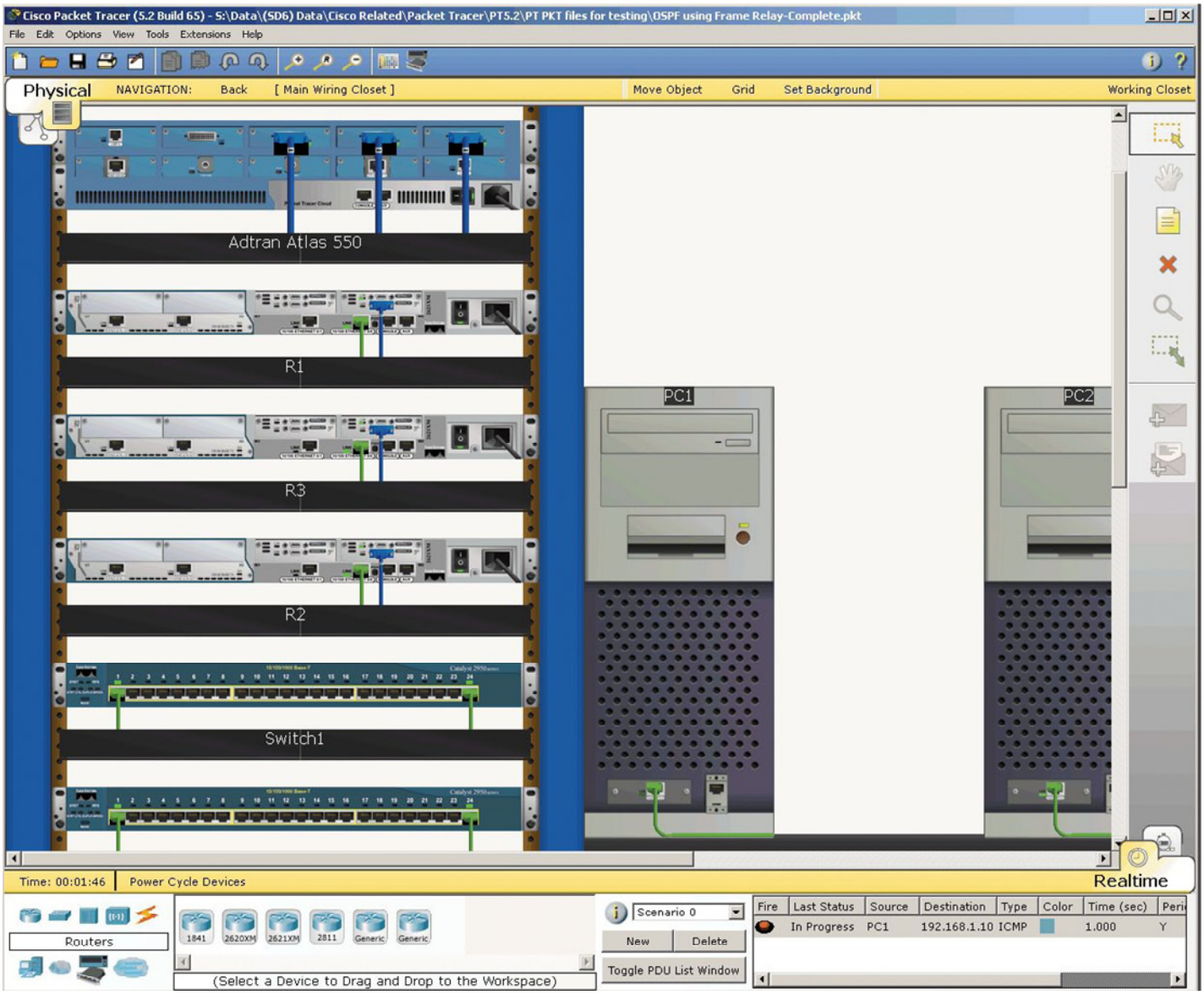


Figure 1. Packet Tracer Logical Output (Cisco, 2010).

this problem state model diagrams (SMDs) were developed. The SMD extracts data from the CLI (Figure 3) and populates contextualized tables (Figure 4).

RESULTS AND DISCUSSION

It has been demonstrated that lecture and workshop material based SMDs can significantly improve educational outcomes (Maj and Kohli, 2004; Maj et al., 2004; Maj et al., 2005; Maj and Veal, 2007). Significantly, these studies have been based on learning problems associated with student's whose first language is not English. The extensive use of diagrams was found to be of considerable assistance to these students.

In order to further improve remote access learning an enhanced, multimedia based interactive interface has been successfully deployed (Figure 5). This system provides:

- Web cam video of equipment being used.
- CLI.
- SMD.
- Voice over IP.
- Webex.

This allows students to dynamically interact with the equipment and the remotely located tutor (Makasiranondh et al., 2011).

Whilst it is a low cost alternative, the main problem with

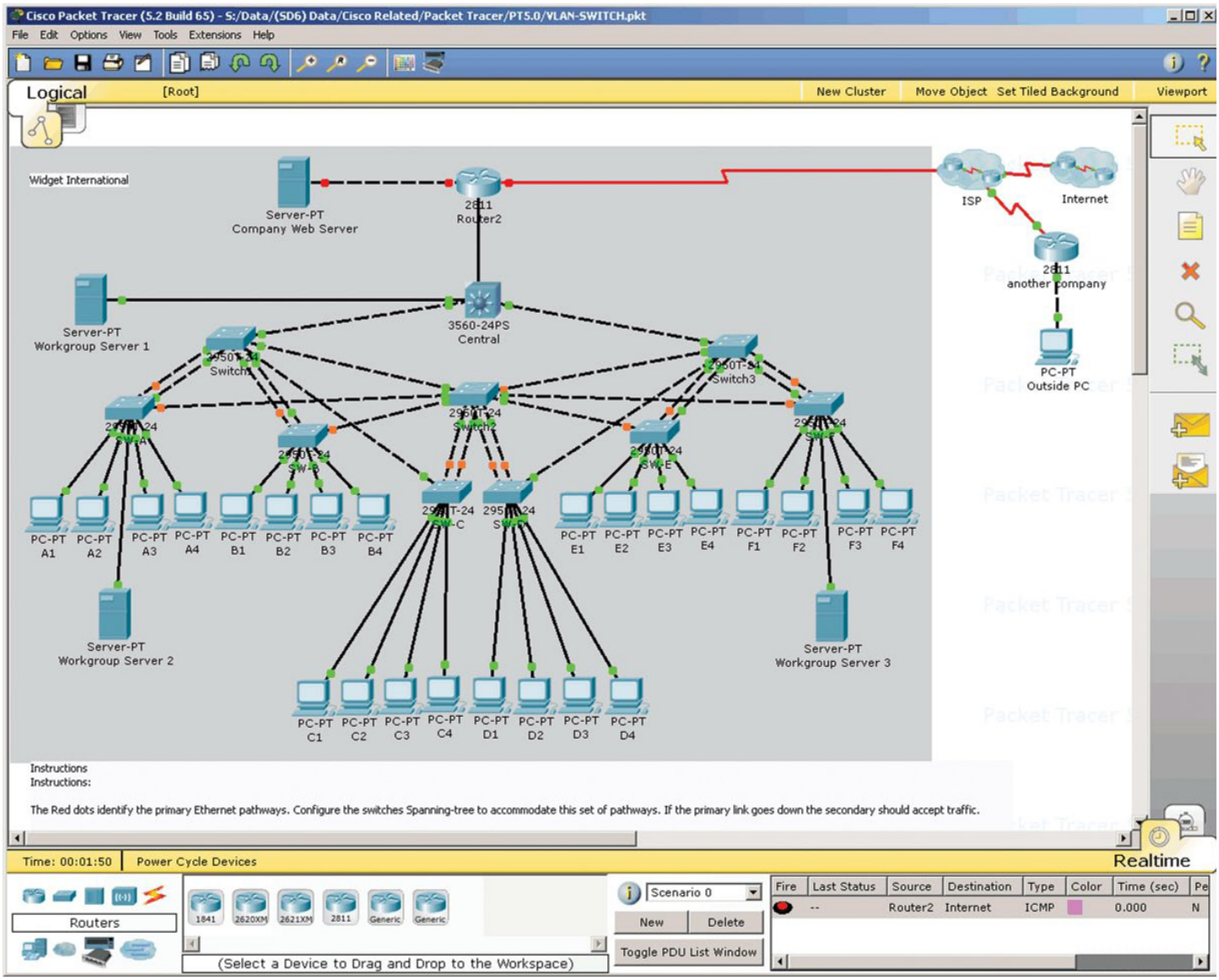
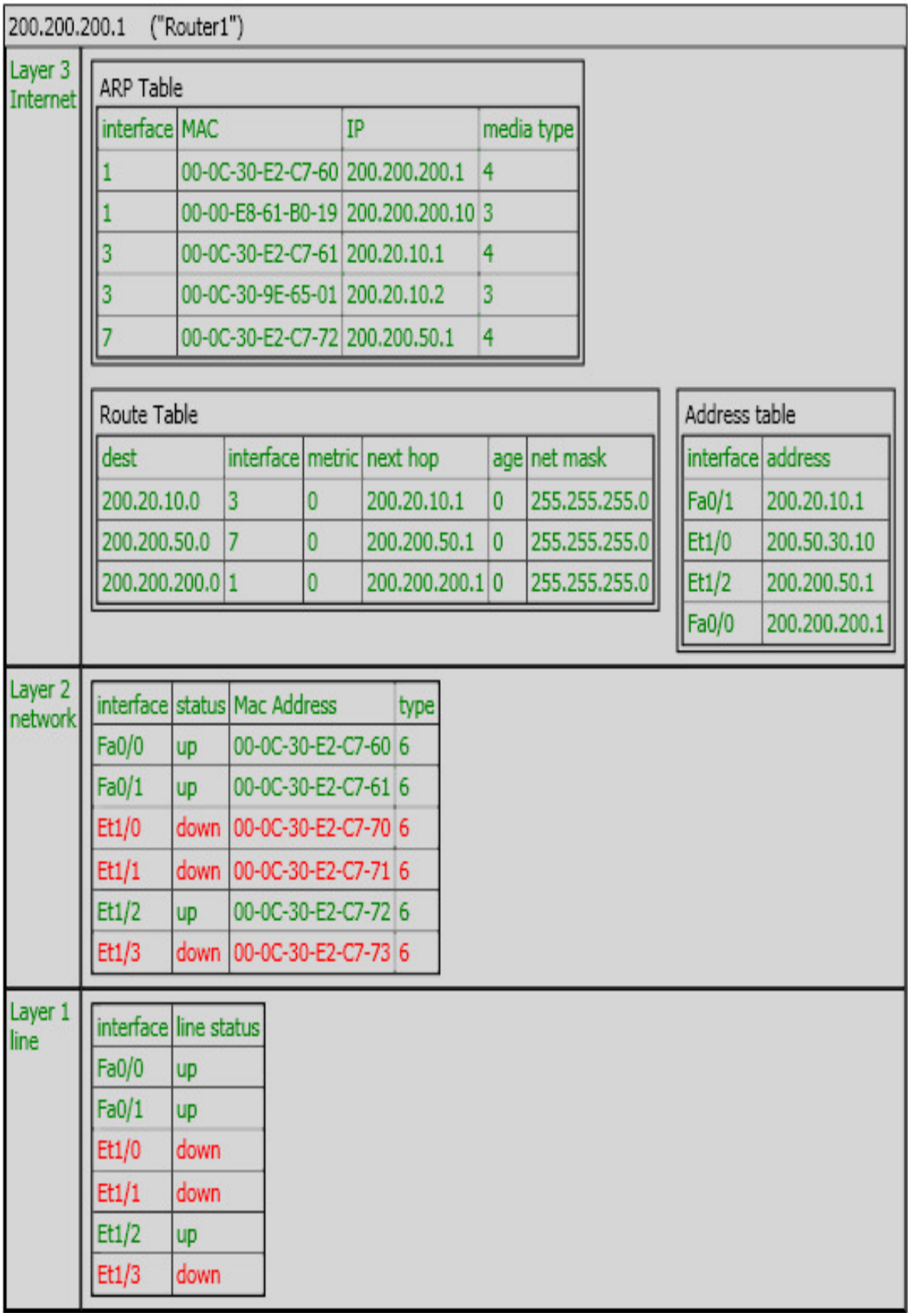


Figure 2. Packet tracer – physical representation (Cisco, 2010).

```
Router1>
Router1>en
Router1#show ip interface brief
Interface                  IP-Address      OK? Method Status                Protocol
FastEthernet0/0            200.200.200.1   YES NVRAM  up                    up
Serial0/0                  unassigned      YES NVRAM  administratively down down
FastEthernet0/1            200.20.10.1     YES manual up                    up
Serial0/1                  unassigned      YES NVRAM  administratively down down
Ethernet1/0                200.50.30.10    YES manual administratively down down
Ethernet1/1                unassigned      YES NVRAM  administratively down down
Ethernet1/2                200.200.50.1    YES manual up                    up
Ethernet1/3                unassigned      YES NVRAM  administratively down down
Router1#
```

Figure 3. Sample CLI output.



200.200.200.1 ("Router1")

Layer 3 Internet

ARP Table

interface	MAC	IP	media type
1	00-0C-30-E2-C7-60	200.200.200.1	4
1	00-00-E8-61-B0-19	200.200.200.10	3
3	00-0C-30-E2-C7-61	200.20.10.1	4
3	00-0C-30-9E-65-01	200.20.10.2	3
7	00-0C-30-E2-C7-72	200.200.50.1	4

Route Table

dest	interface	metric	next hop	age	net mask
200.20.10.0	3	0	200.20.10.1	0	255.255.255.0
200.200.50.0	7	0	200.200.50.1	0	255.255.255.0
200.200.200.0	1	0	200.200.200.1	0	255.255.255.0

Address table

interface	address
Fa0/1	200.20.10.1
Et1/0	200.50.30.10
Et1/2	200.200.50.1
Fa0/0	200.200.200.1

Layer 2 network

interface	status	Mac Address	type
Fa0/0	up	00-0C-30-E2-C7-60	6
Fa0/1	up	00-0C-30-E2-C7-61	6
Et1/0	down	00-0C-30-E2-C7-70	6
Et1/1	down	00-0C-30-E2-C7-71	6
Et1/2	up	00-0C-30-E2-C7-72	6
Et1/3	down	00-0C-30-E2-C7-73	6

Layer 1 line

interface	line status
Fa0/0	up
Fa0/1	up
Et1/0	down
Et1/1	down
Et1/2	up
Et1/3	down

Figure 4. Sample SMD.

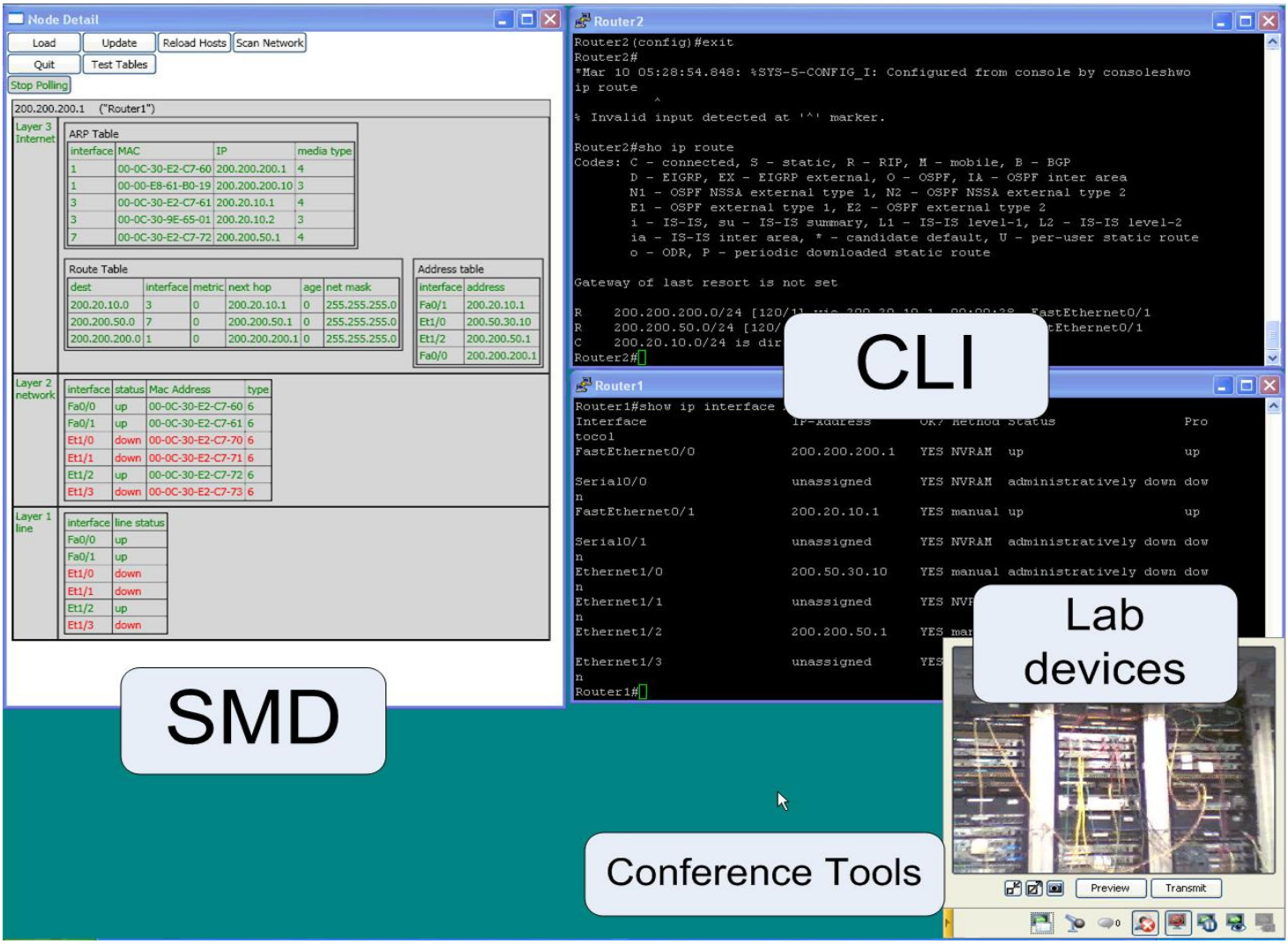


Figure 5. Multimedia enhanced remote access.

packet tracer is the lack of practical hands-on skills development. Second hand equipment is low cost and provides students with the ability to undertake actual workshop exercises. Should this be the preferred option, based on experience the authors recommend the purchase of large quantities of the same device. Hence, device failure will not impact on the teaching program. Furthermore, spare parts may be extracted from surplus devices. The Cisco unified communications package is to be recommended. This could be the preferred option in developing countries as this type of device is most likely to be found in developing countries. The final option that should be considered is the use of remotely located network devices. This has the advantage of providing students access to an extensive range of network devices as zero or relatively low cost. However it is strongly recommended that, should this be the preferred option, that student access is via the enhanced, multi-media graphical user interface. In summary each solution has associated advantages and disadvantages (Table 1).

Conclusions

This paper has shown that economic progress is dependent upon an appropriately trained workforce in ICT. Further that, even though ICT employment prospects are cyclical, there is a global shortage of suitably qualified staff in this field. It is recognized that ICT based educational programs are extremely expensive as they require considerable capital investment. This is likely to be beyond the means of many institutions in some countries.

There are five main solutions to providing ICT curriculum, namely: packet tracer; second hand equip-ment; Cisco unified communications 500 series model

Table 1. Summary.

	Advantages	Disadvantages
Packet tracer	Free software. Runs on standard PC	Does not provide 'hands on' learning
Second hand ICT equipment	Low cost. Provides 'hands on' learning	Reliability may be issue
Cisco unified communications	Relatively low cost Provides 'hands on' learning	Limited technical capabilities
Remote access (Command line interface)	Potentially low cost. Actual cost negotiated with collaborating institution. Access to extensive range of network devices	Complex interface for novices
Remote access (enhanced, multi-media access)	Potentially low cost. Actual cost negotiated with collaborating institution. Access to extensive range of network devices Highly interactive learning environment.	Depends upon reliable communications

540 for small businesses; remote access (command line interface) and remote access (enhanced, multi-media access). Each solution has advantages and disadvantages. Ideally student should be provided with one or more learning options.

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