Open Source in South African Schools: Two Case Studies
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Abstract: One of the major problems facing schools in South Africa is the difficulty in obtaining modern, up-to-date computer facilities. This paper looks at the use of open source solutions in two government schools in South Africa to demonstrate that it is possible for schools to utilise almost any existing computer to provide effective network solutions.

South Africa's curriculum 2005 aims to make computers an integral part of the education system in this country [1]. While this is a very noble goal, it is not one without serious hurdles to overcome. Perhaps the largest obstacle is that South Africa is very much on the underdeveloped side of the digital divide [2].

Many steps have been taken, both by government and industry, to address the issue of computer access in South African schools. There are many projects in place to help schools obtain computers, software, and educators (this last one is especially important, since without training it is impossible for schools to make effective use of computers). Perhaps the largest of these is SchoolNet SA, an organization founded to promote the use of information and communication technologies in Southern Africa [3].

SchoolNet SA has teamed up with many other companies and organizations to achieve their ambition. The result of these partnerships is a good support network for schools in the region, including access to low cost, refurbished computers and network infrastructure through Netday, telecommunications through Telkom, and Internet access through several local ISPs [4].

Arguably one of the more useful contributions was Microsoft South Africa’s announcement in May of this year that it would be providing perpetual free access to the use of selected Microsoft software [5]. It is estimated that this alone will save the South African government many millions of Rand a year.

Unfortunately Microsoft’s contribution highlights one of the fundamental problems afflicting this part of the world. The computer facilities available to most “previously disadvantaged”1 schools fails to meet the system and resource requirements of most modern software.

We can be sure that most of the people who are reading this paper have, at least at some stage, lamented the fact that their computer seems slower than it used to, or that the new version of their favourite software uses even more resources than it used to. When you next do this, consider that a lot of the computers that ICT-disadvantaged schools are using are the computers that the corporate world discarded as obsolete last year, or even three or four years ago.

1 The term “previously disadvantaged” is used in quotation marks here because, although this is the generally accepted term for the schools referred to, I believe that these schools are, at least as far as information and communications technology (ICT) is concerned, still disadvantaged. For the rest of this paper, I’ll refer to these schools as “ICT-disadvantaged”.
The problem lies in getting modern, up-to-date software to run on old hardware. This is something that’s not easy to solve in the traditional Microsoft domain of workstation computers, but is fortunately fairly simple to solve in cases where we are trying to provision network services.

To illustrate this better, this paper will look at two case studies. Both of these involve ICT-disadvantaged schools in Grahamstown, South Africa, and both of them are involved in an outreach programme of the Centre of Excellence in Distributed Multimedia at Rhodes University.

**Case 1: Nathaniel Nyaluza**

Early in 2001, Nathaniel Nyaluza Secondary School in Grahamstown was fortunate enough to win sixteen new computers through a competition organized by SchoolNet SA. Their prize included the network equipment necessary to connect these machines together as a local area network (LAN). These computers have 500MHz Celeron processors, 64MB of RAM and are now, by industry standards, obsolete.

Nyaluza, who had already been involved in the Centre of Excellence outreach project for a number of years, approached various people at Rhodes and asked them for advice on how best to make use of their newly acquired computers. They had an existing network of about five computers (all around the 133MHz Pentium range) and wanted to integrate the new equipment into this network to create two teaching laboratories.

When Nyaluza were asked about what they envisioned their network doing, they had two explicit requirements. Firstly, they wanted to be able to print from any of the computers, and have this printing accounted for in such a way that people could be charged for their use of consumables such as paper. The second requirement was that there be some sort of authentication required to use the computers and, if at all possible, a centralized place where they could store their work. They cited the facilities at St Andrews College (an exclusive private school in Grahamstown) as an example of what they considered ideal.

Unfortunately, while St Andrews has a fairly substantial budget for the computer infrastructure, Nyaluza does not. So the challenge was to try and achieve as much of the functionality as was possible with an absolute minimum of cost.

It was decided to use one of the sixteen computers that had been donated as a central server, and the other fifteen would be used as workstations in the classroom. The machine chosen as the server was upgraded with the addition of a second hard disk drive to provide more storage space for peoples’ work, and a second network card (the device that connects a computer to a network) to allow it to act as a gateway to the rest of the world.

The most obvious way to keep the cost down was to completely avoid commercial software (bearing in mind that this pre-dates Microsoft’s announcement of free software for schools by about a year). Instead, a completely open source approach was taken. This means that the operating system and all the software on the server computer were completely free, achieving our objective of low cost.

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2 A method and philosophy for software licensing and distribution designed to encourage use and improvement of software written by volunteers by ensuring that anyone can copy and modify it freely. [9]
It should be noted at this point that free doesn’t imply low quality – the Apache web server, which will be discussed a bit later, is a completely free, open source product. Currently about 65% of all web servers worldwide use Apache [6], making it more popular than all of its competitors, commercial or otherwise, combined.

It was quickly realised that we could achieve a lot more than the schools requirements by using this approach. A decision was made to give them as fully featured a system as possible, so as to cater for the schools requirements not only now, but in the future as well.

The FreeBSD operating system (http://www.freebsd.org/) was chosen, partly because it has a reputation as a robust platform to run a server on, and partly because those involved were already familiar with it.

**File services**

The donated workstations came with Microsoft’s Windows 98 already installed on them, so the easiest way to achieve the requested authentication and centralised storage (in the form of home directories on the server machine) was to use a primary domain controller³. This approach would also allow us to make use of a shared printer on the client workstations. Fortunately, there is an open source implementation called Samba (http://www.samba.org/) that provides these services, and this was installed on the Nyaluza server.

**E-mail**

One of the most common uses for computers these days is electronic mail, or e-mail. In order to give students and staff at Nyaluza access to e-mail, a mail server was required. Qmail (http://www.qmail.org/) provides a secure, reliable way to do this, and so was installed on Nyaluza’s server machine (which by this time had been christened “nkosi”, meaning “chief” in Xhosa).

A web-based e-mail client called SqWebMail (http://www.inter7.com/sqwebmail/) was chosen to allow people to send and receive mail. Using a web based client has the advantage of allowing the staff and students of the school to retrieve their e-mail from anywhere in the world.

Within a couple of weeks of installing the mail server, it was realised that e-mail viruses would become a serious problem at Nyaluza unless something was done. An anti-virus module for Qmail was installed, allowing all incoming and outgoing e-mail from the school to be automatically scanned for viruses.

At the same time, mailing list software (http://www.ezmlm.org/) and an IMAP server (http://www.inter7.com/courierimap/) were installed. Neither of these are used at present, but provide the school with a fully featured mail server that will cater for any future requirements.

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³ A Primary domain controller is a server, usually running Windows NT, that provides authentication and file services to a number of other workstations. Together, the PDC and these workstations form the domain.
World Wide Web
Another important use of computers these days is access to the World Wide Web. This can be divided into two categories: the ability to look at other peoples’ web pages, and the ability to create your own web page. Nyaluza caters for both these possibilities.

Access to other peoples’ web pages is provided through a Squid caching proxy server (http://www.squid-cache.org/). A caching proxy server makes better use of resources by keeping copies of web pages that are accessed, so that if someone else accesses them again, the local copy is used rather than fetching the page again. Amongst other things, this reduces the time that commonly accessed pages take to load.

Nyaluza also run their own web server, allowing them to host a web page for the school. In addition, each student or staff member can host a personal web page on this web server. The web server software is Apache (http://httpd.apache.org/), which was mentioned earlier. The school’s web page is accessible at http://www.nyaluza.ecape.school.za/.

DNS
In order to give Nyaluza a recognisable identity online, a proper domain name was required. SchoolNet SA maintain the school.za domain, and offer all schools in South Africa a free domain name under it [7]. A request was made, and we were given use of the nyaluza.ecape.school.za domain.

Using a domain like this requires that a domain name system (DNS) server be set up. A DNS server can be likened to a phone book. Each machine on the Internet is assigned a unique number that identifies it, in much the same way that we have a phone number. In order to translate from the machines “name” to its address, we look it up using a DNS server. Just like one gets different phone books for each area, there are different DNS servers for each domain.

nkosi, the server at Nyaluza, runs tinydns as its DNS server, which is part of a package called djbdns (http://www.cr.yp.to/djbdns.html). This server controls the allocation of names in the nyaluza.ecape.school.za domain.

This means that Nyaluza can use e-mail addresses of the form user@nyaluza.ecape.school.za and a website address of http://www.nyaluza.ecape.school.za/ - giving the school a unique web identity.

Printing
Perhaps the most difficult task we tackled at Nyaluza was the setting up of a printing service. While setting up shared printers is a fairly trivial task, accounting for their usage is not. Many modern printers allow you to get a count of the number of pages that have been printed, and this information is commonly used for accounting purposes.

Unfortunately, the printer at Nyaluza doesn’t offer this facility. We had to find some way of counting the pages sent to the printer before they got to the printer.

After many attempts, a solution was found ? convincing the client (the computer that’s trying to print) that it’s talking to a printer that does support this facility. After extracting the page count from the print job, the print job can be converted to a format that the
real printer understands. This conversion is done on nkosi by a program called GhostScript (http://www.ghostscript.com/).

The accounting system uses a MySQL (http://www.mysql.com/) database to keep track of the number of pages each user has printed. A user can have his account credited with a certain number of pages that he’s allowed to print. Each time a page is printed, this number is decremented, and when it reaches zero the user is prevented from printing.

**Administration**

One of the major considerations when setting a system like this up, and perhaps even an implicit requirement, is the need for a relatively simple administration interface. This interface needs to cover at least the basic every day tasks, such as adding and removing accounts, changing passwords and updating printing balances.

Nyaluza’s system uses a text based menu system, implemented using Pdmenu (http://www.kitenet.net/programs/pdmenu/). This menu allows teachers at Nyaluza to perform routine, day-to-day maintenance. In the rare event that more complicated maintenance is required, the machine can be completely remotely administered – we have even upgraded the operating system remotely.

**Connectivity**

Most of the services we’ve mentioned thus far require a connection to the Internet. Some of them, such as e-mail and accessing remote web pages do not require a permanent dedicated connection. It’s perfectly possible to run these services using a dialup account, and many schools in South Africa do this.

Other services, such as DNS and running a web server require that the server be connected to the Internet all the time. This is the case at Nyaluza.

Nyaluza currently gets connectivity through an outreach program of the Centre of Excellence at Rhodes University. Their link to the Centre forms part of an experimental network, in which the use of DSL is being researched. While this link is of a very high speed, such speed isn’t necessary to run the kinds of services that Nyaluza supports. Experience gained from similar installations has shown that it is perfectly possible to run services of this nature on comparatively slow lines.

**Case 2: Nombulelo Senior Secondary School**

While the computers at Nyaluza are already obsolete by today’s standards, they are significantly better than those at Nombulelo Senior Secondary School. Most of the computers at Nombulelo date back to around 1999, and range from high-end 486 machines to early Pentium computers.

If we look at Nyaluza as an example of what can be done with the most basic entry level computers of today, we can look at Nombulelo as what can be done with the bare

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4 Digital Subscriber Line. A technology that allows very high-speed connections over ordinary telephone lines. This technology is widely used in Europe and America, but is still considered experimental in South Africa
minimum of computing power. The central server at Nombulelo is a 66MHz 486 DX2. To give you an idea of the vintage of this machine, consider the fact that Intel discontinued interactive support of the Pentium processor (the successor to the 486) in October 2000 [9]. Despite this, the machine at Nombulelo continues to provide useful service.

Connectivity
All the computers at Nombulelo are connected together using a 10Mbps ethernet hub to form a network. This shared media network is slow by modern standards, but is more than sufficient for the needs of smaller networks. Being connected together allows all machines to access the Internet through a central server, which is known as a “gateway”.

Nombulelo also connects to the Internet through the Centre of Excellence project, through what we term a “dial-dedicated” line. This is a leased line from Telkom that has been connected into the Rhodes PBX system. The result is effectively a 33.6Kbps dial-up line with no call charges – only a fixed monthly rental for the line.

Several attempts have been made at establishing a DSL link to Nombulelo, but it is simply too far away from Rhodes to allow this to work reliably. Even modern technologies such as ReachDSL [10], which is designed specifically for long, poor quality line, fails to negotiate a stable link over the line to Nombulelo.

The gateway at Nombulelo is configured to dial this line on demand, and to do network address translation\(^5\). This allows all the machines on the network at Nombulelo to share the single Internet Protocol address assigned to the modem.

World Wide Web
One of the problems with using a modem to provide Internet access is that it is fairly slow. Modern web browsers attempt to compensate for this by caching a copy of the web pages you visit, so that if you return to the same website again you do not have to download it again. This works very well if there is only one machine using a modem, but falls apart completely when you share this connection.

The solution to this is to run a caching proxy server on the gateway. This performs much the same function as your web browser’s cache, but with the added bonus that you can share documents between computers. When done correctly, this results in a noticeable increase in the speed at which web sites can be accessed.

There are many good caching proxy server products available, such as the one mentioned in the section on Nyaluza. Unfortunately, proxy servers are traditionally very resource hungry, which is a problem on a computer that is seriously deficient of these resources.

Apache, the web server mentioned earlier, has some limited proxy abilities built into it. This is a proxy server in its simplest form, a cache on a local disk. The resource

\(^5\) Network Address Translation (NAT) is a way of mapping many private Internet Protocol addresses onto one public one. This allows, for example, more than one computer to share a modem. NAT is also known as IP Masquerading and Internet Connection Sharing. [8]
requirements of Apache are significantly lower than those of its more complex competitors, which makes it the ideal candidate for a proxy server on an old machine.

E-mail
The gateway server at Nombulelo used to provide limited e-mail abilities to the staff of the school. This was never extended to include students because disk space in the server wouldn’t permit us to house large quantities of mail. This disk space limitation caused us to eventually discontinue the mail server at Nombulelo, and those staff who wish to use e-mail now sign up for accounts through free, web-based providers such as Hotmail or Yahoo!.

Network services
It is worth noting that the gateway server at Nombulelo includes a number of networking services that are normally considered a given. By this I mean services that consume so few resources on a modern machine that people don’t even think twice about running them, but are significant when competing for resources on an older, somewhat underpowered computer.

The dynamic host configuration protocol (DHCP) is used to automatically configure the workstations to use the right IP address, DNS server and gateway. This makes it easy for us to change the network configuration at Nombulelo without it affecting the users in any way.

On a low bandwidth line, the traffic required to perform DNS lookups (that is, to convert a web address to an IP address) is often quite a significant proportion of the total amount of traffic on the line. In the same way as a proxy server caches web pages, we can use a caching DNS server to cache these lookups, resulting in less traffic on the line. This is done at Nombulelo using the dnscache program that is part of the djbdns package that was mentioned earlier.

Administration
One of the most notable things about the gateway server at Nombulelo is that it was first set up in April 1999. Since then it has been running virtually unattended, bar some minor security fixes that have been applied. It is an extremely simple, trouble-free installation that requires a minimum of maintenance. It has been configured to automatically dial up to the Internet at specific known times of the day, allowing us to remotely fix the occasional problem that does crop up.

Conclusions
Both of these case studies show that it is possible to provide modern, high-quality network services to schools using just the sorts of computers that ICT-disadvantaged schools in South Africa are likely to have, or are likely to be able to obtain. Obviously, as is shown by the difference between the services available at Nyaluza and Nombulelo, better computers allow us to provide more services and facilities. That said the configuration at Nombulelo clearly shows that one can provide the most basic of services using even very old computers.
The systems requirements of the computers set up using these open solutions is significantly lower than the requirements of modern commercial software providing comparable services. This is particularly important in helping us bridge the digital divide in countries where computers are a scarce and treasured commodity.

The ideas presented in this paper are even more important in countries where large corporations (such as Microsoft in South Africa) haven’t been forthcoming in their support of education. In these cases, the use of open source alternatives has the additional advantage that they are significantly cheaper than their commercial counterparts.

References