



A HEMISPHERIC INITIATIVE

Thin Client Computing

Installation Manual



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1. Introduction

Most computer networks are *fat client* networks, where each computer on the network is fully responsible for all its processing, so it has to have all the software installed on its local harddrive and enough memory and processing power to run all that software. Unfortunately, these networks are inefficient uses of resources and very costly to maintain. Fed up with managing networks which were increasingly unmanageable, today many network administrators are turning to *thin client networks* as a way to simplify network management and hold their costs at bay. Similar to the old *dumb terminals*, thin clients are only in charge of periodically redrawing the display and receiving the key taps and mouse clicks from the user. In other words, they only handle the user interface. The user's input is passed down the network to a *terminal server* which runs the programs, processes the input, and sends the video output back to the user. Fortunately, the thin client computers of today are much more powerful and useful than the old dumb terminals. Many network administrators advocate them as the solution for standard computer users who only use their computers for mundane computing tasks like word processing, spreadsheet calculations, data entry, web browsing, and email.

Unfortunately, thin client networks can be more difficult to set up than the traditional fat client networks and require a bit more forethought in the planning. This Installation Manual explains in practical terms how to set up a normal thin client network, so that the average network administrator in a business, government, school, or cyber-cafe should be able to follow these instructions. This manual is only meant to be an introduction to the topic, and does not cover the more advanced types of installation, but it does provide the basic step-by-step instructions to get a basic thin client network functioning. Once the basic network is setup, it is much easier to begin experimenting and customizing the network for specific needs. Moreover, it allows network administrators to test the basic functionality and evaluate whether thin client networks can work for their organization. Thin client networks are not recommended for every use, and won't serve the needs of every user. Therefore, it is important to get your feet wet, and test out thin client networks, before implementing them on a production scale. This guide provides the basic steps to begin that process.

This Installation Manual explains the hardware necessary to set up a thin client network. Since many Latin American organizations and businesses don't have a great deal of funding for their IT budgets, this manual focuses on cheaper options and ways to reuse existing hardware.

Given that there are less resources to spend on support contracts, customization, and software licensing, the more expensive software for thin client networks is only given a cursory overview.¹ Instead, emphasis is placed on the less expensive alternatives, along with step-by-step guides on how to install thin client network with few resources and minimal licensing fees. To that end, free/libre/open source software (FLOSS) alternatives are explained in greater detail. A generic installation guide for GNU/Linux thin clients using Edubuntu covers the types of networks used by most schools and educational telecenters. For businesses, governments and cybercafes which don't need the educational software of Edubuntu, there is also a section covering the installation of

¹ Governments and businesses which can afford to use Citrix and other expensive thin client software should probably pay specialists to install and test their systems.

Ubuntu/Kubuntu/Xubuntu. Since the vast majority of Latin Americans are Windows users, there is also a step by step guide for installing Microsoft Terminal Services in Windows Server 2003 r2. To help avoid the expensive licenses of operating systems on the clients and the hardware costs of disks, this manual will explain how to run diskless Windows clients using Thinstation. The goal is to achieve the advantages of stable, secure, and low-cost computing without creating long-term dependence upon the expensive upgrades and support contracts of transnational tech companies.

The wider deployment of thin clients will dramatically lower the total cost of computing, but will just as dramatically reduce the environmental costs of computing. This paper will explain how concerned citizens in Latin America can install thin clients to reduce the production of toxic electronic waste (e-waste) and the consumption of natural resources. Computers consume a great deal of energy whose production contributes to greenhouse gases. A special section explains how to run thin clients on older computers which lack harddrives and CD-ROMs and have less than 64MB of RAM. The guide explains how to install diskless ThinStation clients to work with older Windows machines. For GNU/Linux users, it explains how to implement a minimal install of Debian 4.0r0 with LTSP and a choice of the FluxBox, IceWM, or Xfce windows managers.

2. Hardware to set up a thin client network

Thin client networks can be extremely simple affairs, such as hooking up two computers or extremely complex setups with thousands of clients and hundreds of servers.² Don't let descriptions of the complex server farms scare you from trying to set up a simple thin client network. Many people set up rudimentary thin client networks in their home, so they can give extra life to an old spare computer. Others hook together all the computers their entire house so that all the computers are easier to maintain in a thin client network. If hooking up less than 10 computers, any reasonably new computer should be able to work as the server. For more computers take the time to calculate how much memory and processing power is needed beforehand.

For advanced networks with hundreds of clients, you should plan your network architecture carefully; and set aside a lot of time to test performance and add extra servers if needed. Setting up a complex thin client network requires some experience, so it is a good idea to hire someone who is an expert to setup the system and train your network administrator to run it. For businesses which demand the best performance from their computers, it is worth paying for an expensive support contract with a thin client company like Citrix.

2.1. Buying the server

The server can make or break the performance of the network, so it is important to calculate beforehand what kind of server resources will be needed. A server with inadequate resources can slow the whole network down to a crawl.

The Becta study of British schools using thin clients found that many institutions had underpowered servers which weren't up to the task. The Becta study concluded:

Don't underestimate the capacity of the servers required: where schools ran into difficulty with their implementations, it was usually because the servers were underspecified (in some cases old computers). Those who did not have these difficulties had procured servers with sufficient capacity not only for current needs, but also future expansion.³

When institutions fail to buy an adequate server for their network, people's attitudes toward the thin clients sour and they become resistant and unwilling to use them.

Users are often reluctant to try out the new technology, so it is important that their first experience be a positive one. If there is a long delay between pressing a key and seeing the results displayed on the screen or a multimedia file has choppy playback, they will often reject the new thin clients as inadequate and useless. One commenter on an online forum whose company had unsuccessfully tried to implement thin clients reported that "nearly everyone I've talked to who used them just hated [the thin clients]...there reports of unacceptable latencies, the inability to

2 For an example of a 40 machine Citrix server farm, see the comments at <http://ask.slashdot.org/comments.pl?sid=223912&threshold=1&commentsort=0&mode=thread&pid=18129940#18130160>.

3 "Thin Client Technology in schools: Case study analysis", Nov 2006, Becta ICT Research, http://partners.becta.org.uk/page_documents/research/thin_client_case_study_analysis.pdf.

work when there was a network glitch, etc.” On the same forum, another griped:

Ultimately the latencies are unacceptable, network outages paralyze your entire company, and unless you're doing a lot of stuff that doesn't require computers in the first place the entire effort will not only fail, it will fail miserably. Look at ANY company that has attempted to deploy graphical thin clients and you will find nothing but failure.⁴

These comments about “unacceptable latencies” stem from implementing a thin client network that had inadequate server resources or a slow network.

In order to test whether your server has enough CPU power and RAM, it is important to connect all your clients at once and run many different programs on the clients. Often, the server will appear to work well in initial tests with only a couple clients or with all the clients running the same program. Because of shared memory, it doesn't take much RAM for the server to run the same program on every client. Often all the users will be using the same program at once, such as a word processor and web browser, and the server will only be using 10%-20% of its available RAM, but it is important to have the resources for those situations when people decide to run other applications. Otherwise, everyone's computing will slow down and people will grow frustrated with the system.

The single most important factor for thin client performance is that the server have enough RAM to handle all the clients. A server with inadequate RAM will run fine when only a couple clients are connected or only a few programs are in use, but the performance will rapidly decline when the network reaches full capacity. There will be long delays as programs are swapped in and out of the server's memory. When there isn't enough RAM in the server, LTSP clients will often bootup and allow the user to enter his/her password, but then hang when trying to start X-windows. If X-Windows does manage to start, it will take an intolerably long time for a program to open. On a fat client, when there isn't enough RAM, the user can simply close down extra programs and continue working, but with a thin client, the user is helpless and must simply wait until enough people on the network have closed down memory hogging applications or have turned off their machines. The automatic reflex on a fat client is to simply reboot when computing slows down, but rebooting a thin client will do nothing, because there still won't be enough available memory on the server.

Before buying a server, first check the recommended memory requirements for your thin client server software and then add some. Make sure that your server has extra memory slots available, so that you can add more memory sticks later. If buying RAM for the server, choose faster RAM (although it isn't worth the trouble to buy the very fastest which is designed for extreme overclocking). If your motherboard supports it, choose ECC RAM for error checking.

An inadequate CPU on the server isn't as fatal as lack of RAM, since the thin clients will continue to function, albeit more slowly. When buying the server CPU, remember that it is better to buy dual core or dual processors, rather than opt for a faster single processor. Servers with multiple CPUs can handle more processing threads at the same time, which is important in a network environment with many different programs running.

⁴ <http://ask.slashdot.org/comments.pl?sid=223912&threshold=1&commentsort=0&mode=thread&pid=18129940#18130160>.

If you need more processing power on your network, often it is better to simply add more servers to your network, rather than attempt to upgrade an existing server. If you upgrade an existing server, you will have to take down the entire network, whereas adding an additional server involves no disruption of the network. In this way, older servers can continue running for many years, along side newer servers. Running computers longer reduces the emission of greenhouse gases and the quantity of toxic e-waste. If you decide to add additional servers to the network, however, you may also need to install load balancing software to redistribute processing evenly between multiple servers. See the section [2.4. Scaling up your network](#).

The resources needed for a thin client server can vary widely depending on the operating system, number of clients, and the applications which the clients will use. A GNU/Linux thin client network running K12LTSP or SkoleLinux can get by with less than 50MB of RAM per client if word processing and web browsing are the principal tasks. In contrast, a GNU/Linux server running Edubuntu with multimedia applications will need closer to 128MB RAM per client. Generally, Windows servers running Windows Server 2003 with Terminal Services, Citrix Presentation Server (MetaFrame), or 2X Presentation Server will need more RAM than GNU/Linux servers. Microsoft's forthcoming Windows 2008 Server which is designed for Windows Vista terminals will probably require 3 times more memory and processing power than the current Windows Server 2003. Like Windows Vista, it is probably not worth upgrading to Windows 2008 Server, unless you need its advanced functions like individual application serving. It promises to consume a great deal of resources, while adding little extra functionality.

On the other hand, a GNU/Linux thin client server using LTSP 4.2 with a light windows manager such as IceWM can get by with much less RAM and processing power. In the Sociedad Científica at the Universidad Mayor de San Andres in La Paz, a Pentium 4 1.6 GHz server with 512MB RAM and a 10GB harddrive runs a Debian thin client network with 8 clients. The clients certainly don't get the kind of performance which most business users would require, but they are adequate for teaching GNU/Linux and ordinary tasks. In many cases, thin client networks can function with less, but the central question is what kind of computing tasks need to be done on your clients. Often those tasks require that the server have far more than the recommended minimum.

2.1.1. Recommended requirements for a thin client server

- 512 RAM for the idling server with all of its services.
- 128MB of RAM per client if doing memory intensive tasks such as multimedia and graphic design. Larger networks will have more memory sharing of applications, so 96MB per client may be sufficient. For standard processing such as word processing, web browsing, etc, 50MB per client is probably sufficient, especially on larger networks. If the clients will only be running one or two dedicated programs, the server may be able to get by with as little as 5MB of RAM per client.
- 100MHz of 32-bit processing power or 75MHz of 64-bit processing power per client. Plan on higher CPU requirements if a lot of the clients will be running processing intensive applications at the same time.

- A 10/100/1000BaseT Network Interface Card (NIC) for the thin client network. A 10/100BaseT NIC will work for small networks, but will be slow when all the clients are booting at the same time.
- An extra 10/100baseT NIC for the internet connection.
- 30GB of harddrive space for the server plus storage space for the users.

The amount of harddrive space will vary according to the amount of harddrive space which is allotted for each user. In some public environments such as terminals in a public library, there is no reason to allow users to save to the harddrive. In schools, where there are many users, each user might only be allotted 50MB or 100MB, but in a typical business, each user might be given 5 or 10GB. People working with multimedia might need 50 or 100GB. The harddrives will see a lot of use since multiple users will be trying to access their data at the same time. If you want the fastest harddrive performance, it may be worth paying a premium for SCSI drives, but the amount of harddrive space will be limited since SCSI drives typically have less space than IDE drives. If you want all your user's to be able to access their files quickly, it is probably cheaper to buy 4 SATA drives and implement RAID striping. If you don't want to bother with the hassle of RAID striping, another strategy is buy 4 SATA harddrives and evenly distribute user accounts across the harddrives, so that the number of people trying to access the same harddrive at the same time will be reduced.

It may be worth your time to read the online reviews of the latest CPUs, before deciding which CPU to buy. The situation rapidly changes and what was recommended 6 months ago may no longer be current. In the past, AMD processors were slightly better in terms of performance and significantly better in performance per watt. For people trying to lower their electricity bills, AMD offered substantial savings. Intel, however, has recently bypassed AMD with its new Core 2 architecture. Unlike the Pentium 4 architecture which used vast amounts of energy at high clock rates, the Core 2 is based upon Pentium M architecture which is incredibly energy efficient. Intel's Core 2 Duo is significantly better than AMD's latest Athlon64 X2 both in terms of power and energy efficiency. For higher end server chips, the horse race between Intel's latest Xeon (based on the Core 2) and AMD's latest Opteron is much closer.⁵ This paper lists recommended server configurations using Opterons, because of their better onboard memory controllers, but you can just as easily switch them for servers using Xeons.

In the past, server performance was generally only measured in terms of power. In recent years, however, the amount of energy consumed by servers has skyrocketed. According to a Lawrence Berkeley Lab study, servers and their including cooling equipment in 2005 consumed 5 million kilowatts or \$2.7 billion of electricity in the US, and \$7.3 billion worldwide. In the US, total server energy usage increased 14% per year between 2000 and 2005, effectively doubling within 5 years. If current trends continue, server electricity usage will jump 40 percent by 2010.⁶ Companies like Google which use a lot of computing power have raised serious concerns about

5 donderdag, "Server duel: Xeon Woodcrest vs. Opteron Socket F", Tweakers.net, 7 Sep 2006, <http://tweakers.net/reviews/646>; maandag, "Database test: dual Intel Xeon 5160", Tweakers.net, 13 Nov 2006, <http://tweakers.net/reviews/657/6>.

6 Nate Anderson, "US servers now use more electricity than color TVs", Ars Technica, 15 Feb 2007, <http://arstechnica.com/news.ars/post/20070215-8854.html>.

the increasing energy consumption, arguing that power supplies and CPUs should be more energy efficient. First AMD and now Intel have begun to redesign their processors to consider not only power, but also performance per processing cycling and performance per watt. Given the rising concern about global warming and the reducing reservoirs of fossil fuels, the energy costs of your server should be a fundamental part of your calculations. On average electricity in Latin America costs \$0.10 per kilowatt/hour. Prices vary widely from \$0.04 per kw/h in Argentina to \$0.20 in some Caribbean nations, yet prices are predicted to rise in all of Latin America.

MySQL and PostgreSQL database performance in servers

System	CPU	RAM	Price for 1 CPU (US\$)	Thermal Dissipation Power (W)	Absorbed power under load (W)	Average database performance	Average performance per watt	Average performance per US dollar
Fujitsu Primergy RX300 S3	2 Intel Xeon 5150 (2.66 Ghz) Woodcrest	7GB DDR2-533	\$690	65	294	238032	322	172
Fujitsu Primergy RX300 S3	2 Intel Xeon 5080 (3.73GHz) Dempsey	7GB DDR2-533	\$851	130	447	187924	267	110
MSI K9SD Master	2 AMD Opteron 2216 F-socket (2.4GHz)	8GB DDR-400	\$698	95		181939		130
SUN Fire X4200	2 AMD Opteron 280 (2.4GHz)	8GB DDR-400	\$851	95	341	192740	415	113
SUN Fire T2000	SUN UltraSparc T1 (1GHz) (8 cores)	16GB DDR2-533		79	232	108010	287	

Source: donderdag, "Server duel: Xeon Woodcrest vs. Opteron Socket F", Tweakers.net, 7 Sep 2006, <http://tweakers.net/reviews/646/16>.

When evaluating which CPU to buy for your server, it is important to look more closely at performance per watt, rather than considering just performance or just energy consumption. The new UltraSPARC T1 chip is incredibly energy efficient, but it doesn't provide enough performance per watt to justify using it. Currently, tests of the new "Woodcrest" Xeon, which is based upon the Core 2 architecture, show it to have substantially lower energy consumption, higher performance per watt, and higher performance per dollar than either the old "Dempsey" Xeon or the competing Opteron. If looking for the low energy consumption with high performance per watt, AMD makes a low-energy version of the Opteron which is highly recommended. Likewise, the new "Woodcrest" Xeon is a good choice in terms of energy efficiency balanced with performance.

2.1.2. Example servers:

Up to 10 clients

For up to 10 clients, any recent CPU with 2GB of RAM should work as a thin client server, as long as the clients will just be doing mundane tasks such as word processing, web browsing, etc. If doing processing intensive tasks on the clients, such as Computer Aided Drafting (CAD), buy a fast Pentium Core 2 Duo.

Up to 30 clients

Server with a dual core CPU.

- Intel Core 2 Duo
- 2GB DDR2 RAM
- Motherboard (with integrated 10/100/1000 baseT NIC)

- ATX case and power supply w/350-400W capacity
- 10/100 baseT NIC
- Two 160GB SATA hard drives

Up to 60 clients

Server with a server-grade dual core CPU

- AMD Opteron 175 with dual core 2MB cache
- 4GB ECC DDR2 RAM
- ASUS A8N-E motherboard (with integrated 10/100/1000 baseT NIC)
- ATX case and power supply w/400-500W capacity
- 10/100 baseT NIC
- Two 200GB SATA hard drives

Up to 120 clients

Server with 2 Opteron CPUs and a dual socket motherboard:

- Two AMD Opteron 275 dual core 2MB cache
- 8GB ECC DDR2 RAM
- ASUS K8N-DL motherboard (with integrated 10/100/1000 baseT NIC)
- ATX case and 500W power supply
- 10/100 baseT NIC
- Two 300GB SATA hard drives (or two 160GB SCSI harddrives)

More than 120 clients

The LTSP website estimates that up to 480 clients can theoretically run off one Linux server with dual CPUs, and there are several sites which report running more than 400 LTSP clients per server. Likewise, HP and Microsoft's tests show that up to 200 thin clients can run on a single CPU, 440 thin clients on dual CPUs, and 520 thin clients on four CPUs in a server running 32-bit Windows Server 2003.⁷ Theoretically thousands of clients could run from an server with a 64-bit operating system and 8 or 16 processors,⁸ but it is cheaper to simply add additional servers to your network and use load balancing software to evenly distribute the processing among the servers. Typically a new server is added for every 128 clients for thin clients, however, more processing intensive applications will reduce the number of clients per server.⁹

If your thin client network might expand in the future, it is a good idea to buy a dual processor motherboard and a CPU which can work with a second processor (such as the Opteron 285) so you will be prepared to add a second CPU. Buy the RAM in as few sticks as possible so there will be extra slots in your server for adding more RAM in the future. Otherwise, you will be forced to rip out your existing RAM when upgrading.

7 "Windows Server 2003 Terminal Server Capacity and Scaling", Microsoft, June 2003, <http://download.microsoft.com/download/5/8/c/58ccf087-33c1-41b2-bb74-fe20be37fde6/TermServScaling.doc>.

8 I have been able to find no reports of anyone implementing LTSP with an 8 CPU Linux server.

9 See the positive remarks of Damon10000 in Slashdot about the performance of thin clients in his business where there are 5000 clients and 40 servers (which works out to about one server for every 125 clients). <http://ask.slashdot.org/comments.pl?sid=223912&threshold=1&commentsort=0&mode=thread&pid=18129940#18130160>.

Other things to buy:

- UPS (uninterrupted power supply) for the server (or at the very least, a surge suppressor)
- Surge suppressors for the thin clients
- 2 harddrives and USB enclosure cases to make backups.
- Firewall (can be implemented with software, but stand-alone devices are better.)

When installing the server, you will need to install a CD-ROM and graphics card and connect a keyboard, monitor and mouse. Afterwards these things can be removed, since they aren't really necessary and they consume 70 extra watts. Some computers won't bootup without a keyboard, but changing a setting in the BIOS will make the computer ignore the lack of a keyboard. In GNU/Linux, X-Windows can be configured to use a dummy driver when there is no graphics card. Windows should be able to boot without a graphics card. The server can be maintained by logging in as root from a GNU/Linux thin client or as administrator if using a Windows system. It can also be administered over the internet with SSH.

It is a good idea to not have a keyboard and monitor attached to your server, because it prevents a lot of problems. First of all it reduces the temptation of the network administrator to use the server as a normal computer. Running local applications on the server hogs memory and CPU processing which are better used by the clients. Unlike client applications which can share memory, applications run in the server need their own separate memory space. Moreover, using the server like a normal computer is just asking for trouble. Network administrators by their nature like to experiment with computers, especially when they have as much processing power as a server. They like to test their hardware to its limits and play with new software. These activities can mess up the server's configuration and create opportunities to accidentally erase files or introduce viruses. Removing the graphics card makes using a server an unpleasant visual experience, so there is little temptation to play with it except when necessary.

Furthermore, administering the server remotely, allows it to be stored in a locked room or closet where it is more secure. (Make sure it has adequate ventilation if stored in an enclosed space.) Businesses have good reasons to make sure that their data locked in the server is away from prying eyes. Even in places like classrooms where data security isn't a major issue, a server without keyboard and keyboard can keep curious fingers from playing with the server. In addition, it is a good idea to administer the server from the command line, because it discourages curious bypassers from playing with the server. The command line prompt is downright boring compared to an inviting graphical user interface. LTSP has an option to run the server from the command line, which is a good idea because it frees up RAM which can be used by the clients. Plus, if anyone manages to get into the server, they are less likely to know how to navigate the directory tree from the command line and mess anything up.

2.2. Obtaining thin clients

When looking for thin clients, the first decision is to decide whether to buy new dedicated (“bespoke”) clients or miniature ITX computers, or whether to reuse old computers. Buying new

costs more, but new equipment is easier to setup and generally easier to administer. Buying new is generally worse for the environment since the fabrication of electronics wastes uses tremendous amounts of energy and natural resource, but dedicated thin clients are very energy-efficient. If they last for a decade, dedicated thin clients can save enough electricity to justify the extra costs.

Reusing old computers as thin clients is cheaper and better for the environment, since new toxic e-waste will not be created. On the hand, old computers will consume more electricity to operate. Plus, reusing old computers takes a lot more time to setup and administer. Expect to spend more time tinkering with the equipment, especially if trying to use computers which are more than a decade old. Setting up diskless thin clients with Pentium IIIs is generally a painless process, but setting up diskless clients with old Pentium Is and 486s often requires installing extra RAM, and fiddling with the network interface card (NIC). If using Windows Terminal Services with clients which have a local operating system, expect to spend more time reinstalling software and replacing old harddrives which have a high failure rate. If your labor is cheap and you don't have a large budget for new equipment, reusing old computers is the best course, but be prepared for a few extra hassles when dealing with decade-old equipment.

2.2.1. Dedicated thin clients

The easiest way to set up a thin client network is to simply buy new dedicated thin clients, which cost anywhere between US\$150 and US\$600, depending upon their capabilities. In the past, these machines often lacked ports and the ability to store data locally, but today most of these machines have USB ports and Flash memory drives.

Dedicated thin clients are incredibly energy-efficient compared to a normal computer, using anywhere from 6 to 40 watts, which is far less than the 150 to 350 watts used by typical computers. With average electricity prices at 0.10 per kilowatt-hour in Latin America, this can represent substantial saving on the electric bill. Plus, using less electricity means that less fossil fuels will be burned, so there is less production of greenhouse gases which cause global warming. The savings to your energy bill and the reduction of greenhouse gases depends where you live and how your electricity is generated. Some countries like Argentina have very cheap electricity at only \$0.04 per kilowatt-hour, but people living in the Caribbean can pay five times as much for their electricity. Check the table in **Appendix B: Calculating Costs and Energy Use** for electricity prices per kilowatt-hour to find out how much electricity costs in your country. Likewise, the environmental damage caused by electricity generation varies widely from country to country. In countries like Paraguay where almost all electricity comes from hydroelectric power, electricity generation creates few greenhouse gases.¹⁰ In contrast, the environmental impact is much higher in places such as the Caribbean where almost all electricity comes from fossil fuels.

The biggest harm to the environment is caused when computers are initially created since a great deal of natural resources and energy are lost in the creation of electronics. A dedicated thin client takes far fewer resources to fabricate compared to the average computer and 17" monitor which

¹⁰ Constructing hydroelectric dams in tropical forests can cause a lot of CO₂ and methane because the rising waters cause the vegetation to rot. A study of a dam financed by the World Bank in the Amazonian basin showed that it caused more environmental damage than a conventional generator which used fossil fuels.

uses up 6400 megajoules of energy, 240 kg of fossil fuels, 22kg of chemicals, and 1500kg of water in the fabrication.¹¹ A thin client lasts 2 to 3 times longer than the standard computer, so 2 to 3 few computers are bought, saving a huge amount of natural resources. Because many thin clients don't have moving parts, they have a much lower failure rate. VXL Instruments estimates that the Mean Time Before Failure (MTBF) for their thin clients is 120,000 hours compared to 25,000 hours for a conventional computer.¹² Parts rarely have to be placed on thin clients, saving time and money to manage a thin client network. In addition, less toxic e-waste is created with thin clients, which in Latin American is generally disposed of unsafely. Since most Latin American countries don't have recycling programs for electronics, most old computers will be discarded in unlined landfills that allow their lead, mercury, cadmium, brominated flame retardants, phthalates, PVC, phosphorous, cadmium, barium, zinc, and vanadium to leech into the soil and water supply.

Dedicated thin clients are small and unobtrusive. Many are designed to strap on the back of an LCD screen, so they take up no extra space on the desk. Plus, most thin clients operate without the constant whirring of fans, so they operate well in quiet places where people need to concentrate with few distractions. Because they generate little heat, they can use passive cooling systems and be totally enclosed to operate in dirty and dangerous environments. For instance, they can function in places where dust or acids in the air would damage a conventional computer with a fan cooling system.

Most importantly, dedicated thin clients save a lot of time to administer. They are very simple to install—in most cases they only need to be plugged into the network and they will automatically work. If they fail, they can be just as easily replaced with no time wasted reinstalling the OS and applications. The downside to dedicated thin clients is that they are not very upgradeable, nor very configurable. Most allow more RAM to be added, but otherwise they are essentially sealed boxes. If you want to add more components like an optical drive or a floppy drive, they have to be connected via USB ports. If the freedom to add new components is important, consider buying miniature computers with an ITX form factor.

2.2.2. Miniature ITX computers

ITX computers can be found for roughly the same price as dedicated thin clients, but they will require a little more work to setup. If you are using a diskless thin clients, you will just have to enter the BIOS and enable PXE. But if you plan to have the clients running an operating system locally (which is often the case with Windows Terminal Services), then you will have to install an operating system. Like dedicated thin clients, ITX computers consume fewer resources to fabricate and less energy to operate. AMD created a prototype ITX design which only uses 6 watts.

The advantage of ITX computers lies in their ability to be customized to your specifications. If you have special requirements or simply like to build your own computers, the ITX form factor

11 Eric Williams, "Energy intensity of computer manufacturing: hybrid analysis combining process and economic input-output methods", *Environmental Science & Technology*, Oct 2004, 38(22): 6166-6174. Abstract: <http://pubs.acs.org/cgi-bin/abstract.cgi/esthag/2004/38/i22/abs/es035152j.html>.

12 "Think Thin: Benefits of Thin Clients", VXL Instruments, <http://www.vxl.net/clients/clients.html>.

gives you that freedom. Dedicated thin clients lock you into the proprietary hardware of a company like Wyse, Neoware, Fujitsu or VXL instruments, but ITX computers allow you to use standardized parts which are cheaper and easier to find. For instance, most dedicated thin clients don't have adequate sound and graphics processors, unless you pay a premium for special multimedia thin clients, which cost almost as normal PCs. If you need a multimedia client, you can build an ITX computer with a good graphics processor and sound card for cheaper than what is offered by the thin client companies. The downside is that you will spend a lot more time doing it yourself and it is harder to find tech support for your custom machines.

2.2.3. Reusing old computers

The cheapest and most environmental option is to take old PCs and convert them into thin clients. Thin clients can be old machines, in fact downright ancient. Fifteen year old 486s loaded with extra RAM can function as LTSP thin clients or Windows 95 clients using Windows Server 2003 Terminal Services. Millions of old computers gathering dust in closets and store rooms and old computers can be acquired for a song since they are perceived as having no value. Schools, telecenters, and community organizations may be able to acquire client computers for free as donations. If setting up diskless clients, it should be much easier to find available computers for your network. The first part of computers to fail are the drives, since they contain moving parts, so many older computers are abandoned due to bad harddrives, CD-ROMs or floppy drives. These abandoned machines can be resurrected as diskless clients for little cost.

Setting up a thin client network with old equipment can require a lot of time and patient trial and error. The older the equipment and the more diverse the equipment, the more time you will probably spend getting everything to work properly. It is easiest when all the clients are the same model or general type of machine. If possible, look for old equipment which businesses or governments are discarding, since they often buy the same types of computers in large lots.

2.2.4. Buying used computers

When buying a normal computer, people generally look first at the processor speed, but the processor in the client isn't responsible for doing much (unless you are running a hybrid client which has local applications).

When searching for clients, look these factors in order of importance:

1. Quantity and speed of RAM (if little RAM, needs extra slots so more can be added)
2. Quality of graphics card
3. Speed and type of processor
4. Speed of motherboard bus
5. Sound card
6. Has USB ports? Does it support USB 2?
7. Speed of network interface card (preferably 10/100Mb/s)
8. If diskless thin client:
 - PXE support in motherboard? (Most motherboards after 1999 had PXE.)
 - If no PXE support, does the network interface card work with EtherBoot?
 - Is there an available floppy drive, harddrive or CD-ROM to load EtherBoot?

9. If the thin client is running a local operating system:
 - Harddrive
 - CD-ROM (or floppy drive) to install the operating system.

2.2.4.1. RAM

A Pentium I with 128MB of RAM is a more useful thin client than a Pentium III with 32MB RAM, because it can run a lot more applications. Old computers can be turned into adequate thin clients by filling up all their RAM slots. Unfortunately, it can be difficult to find the kind of RAM which is used in old computers and it often takes some searching. In many Latin American cities there are markets for old computer parts and old RAM can be picked up cheaply. When shopping for used RAM, know exactly what type of RAM you need. Some older computers only accept RAM in pairs. Look up your motherboard online to see whether it accepts higher capacity RAM and whether it has to be installed in a special way. Sometimes the documentation for old motherboards is no longer available—check eServiceInfo.com which has the tech docs for thousands of products.

2.2.4.2. Graphics cards and sound cards

Most people who want good multimedia performance create networks of fat clients, but these require a lot more time to administer than thin clients. If you want adequate multimedia performance but also want the benefits of centralized administration with a thin client network, read the section [5. Improving multimedia capabilities in a thin client network](#). Rather than buying special multimedia thin clients, the cheapest way to accommodate multimedia is to buy old Pentium 4 PCs with good graphics and sound cards. They may not support DirectX 10, but they should be adequate for most tasks.

If you are using GNU/Linux, check first on linuxcompatible.org whether a particular graphics card or sound card is supported in GNU/Linux. If you don't have access to the internet when buying, try booting the computer with a GNU/Linux Live CD and check whether the graphics and sound work properly. Almost all the major GNU/Linux distributions now make Live CDs which allow the machine to be booted from the CD rather than the HD. The beauty of Live CDs is that they don't touch the existing harddrive, so you check out a machine with GNU/Linux, but it will return to normal after you pop out the CD and reboot. If the computer doesn't have a CD-ROM, you can still test whether the sound and graphics works by booting from a USB Flash memory drive. There are several GNU/Linux distributions which are designed to boot from USB Flash memory. If you have limited space on your memory stick, Damn Small Linux has a version which only uses 50MB. Older computers generally don't support USB booting, but newer computer often have this option in the BIOS. Reboot the computer and enter the BIOS (by pressing some key like ESC or F2 while booting). Set USB as the first device in the boot order. Then reboot with the flash memory stick in a USB port.

2.2.4.3. USB

USB flash memory sticks have become an essential part of modern computing, replacing the floppy as the preferred way to carry around personal files. Unfortunately older computers often don't have USB ports, or only support the slower USB 1.1 standard. If you want your thin clients

to be used to their full potential, it is essential that they have USB ports. If not, check to see that there are free PCI slots so you can install a PCI card with USB ports.

2.2.4.4. Network Interface Card (NIC)

It is recommended that the NICs in the clients be PCI and support 10/100 Mb/s speeds. It is possible to use the older PCI 10Mb/s cards and ISA cards, but there will be noticeable delays when loading and saving large files. Video playback may also be affected by the slower network speeds of 10 Mb/s, since it can cause stuttering and noticeable pauses in the video. The server should have a 10/100 NIC for the internet or to connect to the wider network, plus a 10/100/1000 NIC for the thin client network (although it can get by with 10/100 Mb/s for a small thin client network which won't have much multimedia).

2.2.5. Diskless thin clients

Diskless thin clients boot from the network. Instead of loading the operating system from the harddrive, they connect to the server and download the operating system and load it into their RAM. There are several ways to control the network interface card so it will download the operating system. The easiest way is to use the Pre-eXecution Environment (PXE) protocol which was developed in 1999 by Intel. Most modern motherboards support this option, but it needs to be enabled in the BIOS.

If buying an computer with an older motherboard which doesn't support PXE, then operating system can be downloaded with EtherBoot. Unfortunately, EtherBoot doesn't work with all Network Interface Cards. Check this [list of NICs](#) to see whether EtherBoot supports your card and whether you will have to do anything special to enable it. See the section [4.6.3.3. Making an EtherBoot boot floppy disk](#). In my experience, many of the cards which are supposedly supported, still won't work properly. The older ISA cards can be especially difficult to configure to work with EtherBoot. If you run into problems with your NIC, it is much easier to buy a new NIC rather than fiddling with the old card. New NICs can be found for as little as \$4 or \$5 each. NICs using RealTek 8139 and SIS900 controller chips are recommended as working with EtherBoot. In addition to a NIC which is compatible with EtherBoot, the computer will also need a working floppy, CD-ROM or harddrive to load the EtherBoot program.

2.2.5.1. Thin clients which boot from local harddrive

If your clients will be running a local operating system (rather than booting from the network), they will need a functioning harddrive. Older harddrives are notorious for disk failures, so running thin clients from harddrives might not be as reliable as diskless thin clients.

If you are using Windows, remember that you are legally obligated to buy software licenses for those old operating systems. Microsoft doesn't offer discounts for its old versions of Windows, so you will have to pay the same price as if buying a license for Windows Vista. In fact, the Microsoft website says that you have to buy a license for Windows Vista or XP, if you want to run Windows 3.11/95/98/ME/2000 on your client. The best way to get around this licensing silliness is to install GNU/Linux on your client and use rdesktop to display the Windows terminal. rdesktop is compatible with Windows NT4 Terminal Server, Windows 2000 Server and Windows

Server 2003. The other solution is use ThinStation or 2X PXES to make a diskless client, so the client doesn't need a license for the Windows operating system. Even if the clients aren't using Windows, they still a Terminal Services Client Access License (CAL) to access a server running Windows NT, Windows 2000 Server or Window 2003 Server.

2.3. Networking hardware

The server needs to be connected to the clients. The cheapest way to do this is to use ethernet cables and a switch. If there are obstructing walls which make it impossible to run cables, then an [LTSP wireless network](#) can be constructed, although some report that the delays in wireless are unacceptably long. If you want to use wireless diskless clients, normal wireless won't work with etherboot, which is the program used by LTSP, 2X PXES and Thinstation to boot off the network. The only way to get wireless clients to boot from a network is to use a [wireless ethernet bridge](#) like Asus' [WL-330g](#). If your network extends over long distances, it may be necessary to lay fiber optic cables or use an internet connection.

The quality of a network is measured according its bandwidth (the amount of data that can travel over the network within a given period of time) and latency (the time it takes a packet to reach the other end of the network). If there is a noticeable delay between the time a key is struck and the results are displayed on the screen of the client, the problem generally related to latency. This can especially be a problem if networking through multiple hubs/switches or over the internet. The amount of traffic which will pass down the network lines varies greatly according to color depth, screen resolution, and types of applications. Multimedia will use a lot more bandwidth, as do 24-bit or 32-bit color. Lack of bandwidth can be a problem when streaming video and audio or when many diskless clients are all trying to bootup at the same time and they are all trying to download their operating system at the same time from the server.

If trying to calculate the amount of network traffic, each client using Windows Server 2003 Terminal Services and running standard office software will use roughly 1150 bytes/sec if in 8-bit color (256 colors) and 1450 bytes/sec if in 16-bit color (65536 colors).¹³ It is generally recommended to allow for roughly 1 Mb/sec per client to avoid bandwidth problems.¹⁴ Figure much higher bandwidth for multimedia applications.

2.3.1. Networking two computers

All it takes to create a thin client network with two computers is a cross-over ethernet cable, hooking the client to the server. In a cross-over cable, the positions of the wires are switched, so that wires carrying the output from one computer become the input for another computer. This allows two computers to be hooked together without using a switch (or router). Before investing in a lot of expensive networking equipment, it is recommended that you first test whether your server and clients actually work together with a simple cross-over switch.

¹³ "Windows Server 2003 Terminal Server Capacity and Scaling", Microsoft, Jun 2003, <http://download.microsoft.com/download/5/8/c/58ccf087-33c1-41b2-bb74-fe20be37fde6/TermServScaling.doc>.

¹⁴ Recommended in: Francis Giraldeau, Jean-Michel Dault and Benoit des Ligneris, "MILLE-XTERM and LTSP", Linux Journal, 28 Aug 2006, <http://www.linuxjournal.com/article/9097>.

The crossover cable plugs directly from the RJ-45 jack in the server's network interface card (NIC) to the client's NIC. If both computers have a 1000 megabits per second Network Interface Cards (NICs), then look for higher bandwidth Cat5e (Category 5 enhanced) cable. For slower 10 or 100 Mb/s networks, ordinary Cat5 cable will do. If you like to tinker, see [these instructions](#) (or [en español](#)) for making your own cross-over cable.

2.3.2. Networking three or more computers

With three or more computers, all the computers should be connected to a network switch in a normal star configuration. This means that each computer is connected to the switch, rather than directly connecting computer to computer.

It is recommended to buy a managed switch with full duplex (capable of transmitting and receiving at the same time). A hub may work in place of a switch for small networks, but hubs can cause problems with larger networks. Unlike switches which transmit only to the designated port, hubs transmit the signal to all the ports, which can create signal conflicts on the network. Hubs also slow down all the traffic to half duplex mode, so they can't both send and receive at the same time. Avoid buying cheaper switches which only have one LED indicator light per port. Instead, look for a better switch which has 3 indicator lights for LNK (link), TX (transmitting), and RX (receiving) which will facilitate diagnosing problems. When connecting computers to switches, use normal “straight through” cables, rather the “cross-over” cables. Most cables are “straight-through”, but you can check whether your cable is a cross-over by examining the colors of the 8 wires in the connectors. If the wires have the same order at both ends of the cable, then the switch is a “straight-through”. If the order of the wires is switched then it is a “cross-over”.

2.3.3. Network speed

Because the server has to communicate with every other client on the network, the connection between the server and the switch will have a much higher traffic load than the other connections on the network. To prevent a potential bottleneck, the connection should be at least 100 Mb/s for a small network. Servers with more than 20 or 30 clients should have a 1000 Mb/s connection to the switch. Now-a-days, it is easy to find motherboards with integrated 10/100/1000BaseT NICs and you can also buy them on PCI add-in cards for \$25-\$35. If the network will be used to stream multimedia or play graphics-intensive games, plan on installing a 1000 Mb/s connection between the server and the switch and at least 100 Mb/s between the clients and the switch.

Networking standards and their characteristics

Standard	Speed	Max. cable length	Cable type	Connector
10BaseT	10 Mb/s	100m	Cat3 or higher (Cat5 is recommended), UTP or STP	RJ-45
100BaseTX	100 Mb/s	100m	Cat5 or higher, UTP or STP	RJ-45
1000BaseT	1000 Mb/s (1 Gb/s)	100m (from 75-150m depending on manufacturer)	Cat5e or higher, UTP	RJ-45
10GBaseT	10000 Mb/s (10 Gb/s)	30m on Cat5e, 55m on Cat 6, 100m on Cat6a or Cat7	Cat5e or higher, UTP	RJ-45

10GBaseCX4	10000 Mb/s (10 Gb/s)	15m	InfiniBand copper wire	
10GBaseSR	10000 Mb/s (10 Gb/s)	300m (varies with cable type)	Fiber optic with 850nm wavelength	
10GBaseLR	10000 Mb/s (10 Gb/s)	10km (varies with cable type)	Fiber optic with 1310nm wavelength	
10GBaseER	10000 Mb/s (10 Gb/s)	40km (varies with cable type)	Fiber optic with 1550nm wavelength	

Source:¹⁵

The connection is only as fast as the slowest component. For instance, to get 1000Mb/s bandwidth, both the NIC and the switch have to be capable of 1000Mb/s. Although the maximum length of Cat5, Cat5e, and Cat6 is rated at 100 meters, in practice the distance is often less, especially when the wires are not twisted properly or lower quality NICs don't transmit a strong signal. If you need to connect computers that are longer than 100 meters apart, insert a repeater or an active hub to strengthen the signal. At 10 Mb/s, the maximum possible distance between a server and client is 500 meters, using five Cat5 cable segments and four intervening repeaters. 100 Mb/s is less fault tolerant, and will only allow a maximum possible distance of 200 meters with 1 intervening repeater. If you need to connect over longer distances, you will need to lay fiber-optic lines or consider using conventional broadband internet to communicate between the server and the client. Fiber-optic requires expensive equipment and special care to align and install correctly.

2.3.4. Rules for using repeaters with 10BaseT and 100BaseTX

10BaseT (shielded and unshielded twisted pair 10Mb/s)

There can be up to four 10BaseT repeaters (active hubs) between the switch and any workstation or server. Only three of the repeaters, however, can have devices attached.

Use the 5-4-3-2-1 guideline for 10baseT networks:

- Five segments are allowed
- Four repeater hops are allowed
- Three repeaters can have clients attached
- Two segments can't have clients attached and are links only
- All of this makes one collision domain with a maximum of 1024 nodes

100BaseTX (shielded and unshielded twisted pair 100Mb/s)

Only one repeater or active hub is allowed between the switch and any workstation or server. The total distance between the switch and a client on the other side of a repeater or active hub can't exceed 200 meters.¹⁶

¹⁵ Jeremy Cioara, *et al.*, "CCNA Exam Prep: Data Link Networking Concepts", 3 Feb 2006, <http://www.examcram2.com/articles/article.asp?p=438038&seqNum=3&rl=1>; Team uCertify, "Overview of Networking Technologies," 5 Oct 2006, http://www.webknowhow.net/dir/Other_Resources/articles/061005networkingtechnologies.html; "10 gigabit Ethernet", http://en.wikipedia.org/wiki/10_gigabit_Ethernet.

¹⁶ "Intel® Express 10/100 Fast Ethernet Switch: Repeater Count Limitations", <http://www.intel.com/support/express/switches/10100fast/sb/cs-010971.htm>.

2.3.5. Expanding an existing network

If you want to expand your existing network, but find that your switch (or hub) has run out of available ports, you can add extra switches to the network. Use “cross-over” cables to connect together two switches. (Some of the newer switches will accept either “cross-over” or “straight through” cables when connecting to another switch.)

2.3.6. Networking over the internet

If people need to connect to your network from even longer distances or while roaming, they can use conventional internet to connect to the server. Unfortunately, the connection on a wide area network (WAN) will not be nearly as reliable as in a local area network (LAN).¹⁷ For remote connections tunneled over the internet, consider using compression software such as NX to reduce the bandwidth needed to run remote desktop software. Although NX is generally used to compress X-Windows, it can also be used with Microsoft's Remote Desktop Protocol (RDP) or Virtual Network Computing (VNC).

2.3.7. High bandwidth networks in the future

Currently network traffic in large enterprises is doubling every year due to the increased use of streaming video, Voice over IP, network file storage, and document imaging. These leaps in network traffic suggest that thin client networks will also need to increase their connection speed in the future. A thin client network which has hundreds of clients and uses multimedia may need the higher speeds of 10 Gb/s between the server and the switch. Currently 10 Gb/s connections are generally not used because they require the use of fiber-optics which are extremely expensive and require special hardware to convert the signal to copper which can be plugged into the back of a computer. Fiber-optics work well for network backbones, but they aren't designed for connecting a server to a switch. Currently the only feasible option for a 10 Gb/s connection is 10GBaseCX4, which requires special InfiniBand cabling and connectors and is limited to 15 meters in length.¹⁸

In June 2006, however, the new 10GBaseT standard was approved to use copper unshielded twisted pair (UTP) wiring and standard RJ-45 jacks. It is expected that 10GBaseT will cost \$1000 per port (which is far less than \$3000 per fiber-optic port), but these prices may fall rapidly as manufacturers gear up production.¹⁹ If you have a server with hundreds of thin clients which use multimedia, it is worth keeping your eye on the price of 10GBaseT switches and NICs since it may become a feasible option in the next couple years.

17 For a study of the problems of low bandwidth performance with thin client networks, see: S. Jae Yang, *et al.*, “The Performance of Remote Display Mechanisms for Thin-Client Computing”, Proceedings of the 2002 USENIX Annual Technical Conference, Columbia University, June 2002, http://www.ncl.cs.columbia.edu/publications/usenix2002_fordist.pdf.

18 For available products, see: Phil Hochmuth, “10G Ethernet vendors look to stoke demand,” *Network World*, 8 Nov 2004, <http://www.networkworld.com/news/2004/110804tengig.html?page=1>.

19 Fahmida Y. Rashid and Frank J. Ohlhorst, “Stepping Up To 10G: Get ready for the next big ascent as the network upgrade cycle gains steam”, *CRN Tech*, 21 May 2007, <http://www.crn.com/article/printableArticle.jhtml?articleId=199601946>.

2.4. Scaling up your network

Thin client networks can start as very simple affairs with a couple computers hooked together by a \$15 switch and a couple ethernet cables, but the biggest benefits of thin client networks lie in large networks. As the network grows, it achieves economies of scale in terms of maintenance and labor costs. It does not cost significantly more to maintain a network of 3000 thin clients than 300 thin clients. In the US, here are reports of large companies paying only 1 technician per every 1000 thin clients. Achieving these sorts of efficiencies, however, require careful planning and testing of the network. It is beyond this guide to give a complete discussion on creating large scale networks, but it can provide a few basic pointers to get you started.

The beauty of thin client networks is their ability to grow and add resources when needed. In a single computer, it becomes dramatically more expensive to keep adding additional memory and processing power, and ultimately a practical limit is reached. Adding more RAM can also become a fool's quest since there are limited number of available RAM slots, so the old RAM has to be ripped out to make room for higher capacity RAM. Replacing a slower processor with a faster processor often involves replacing the motherboard (and often the RAM). Likewise, the motherboard and often the RAM and operating system has to be replaced to add additional processors.

Upgrading to a faster processor and adding additional processors to the terminal server yields diminishing returns. The HP and Microsoft study about thin client networks using Windows Server 2003 showed that increasing from 1 processor to 2 processors in the server may cause significant gains for “data entry” clients only running one program (Excel), but the gains are less significant in clients for “knowledge workers” running 4 programs (Excel, Word, Outlook, Internet Explorer) at the same time.

Increase in maximum number of thin clients

Upgrade inside server	Knowledge worker		Data entry workers	
From 1 to 2 Xeons	From 140 to 200 clients	43% increase	From 200 to 440 clients	120% increase
From 2 to 4 Xeons	From 200 to 270 clients	35% increase	From 440 to 520 clients	18% increase

Tests with HP servers, Xeon 2.4GHz 2MB L2 Cache, 4GB RAM, Windows Server 2003.

Source: “Windows Server 2003 Terminal Server Capacity and Scaling”, Microsoft, June 2003,
<http://download.microsoft.com/download/5/8/c/58ccf087-33c1-41b2-bb74-fe20be37fde6/TermServScaling.doc>.

Often network administrators will add a second processor to a server, rather than buying a new server, since it is cheaper. However, it makes no sense to upgrade from 2 to 4 processors, since the cost of a quad processor server is dramatically higher and the margin of return is so low. Likewise it generally doesn't make sense to upgrade to a faster processor, since the margin of return doesn't justify the expense. In the HP and Microsoft study, increasing the processor speed 20% (from 2.0GHz to 2.4GHz) only increased the maximum number clients by 13%.²⁰

Adding more RAM to the server will improve performance up to a certain point, but beyond that

²⁰ “Windows Server 2003 Terminal Server Capacity and Scaling”, Microsoft, June 2003,
<http://download.microsoft.com/download/5/8/c/58ccf087-33c1-41b2-bb74-fe20be37fde6/TermServScaling.doc>.

point adds little to performance and won't increase the maximum number of clients. Part of the problem is that 32-bit operating systems like Windows Server 2003 can only address 4GB of memory space. Windows Server 2003 has been tuned to better utilize the available memory space than Windows 2000 Server, so it can serve roughly 80% more clients.

Maximum number of thin clients running Windows 2000/2003 Server

Upgrade	Knowledge workers	Data entry workers
Windows 2000 Server	160	230
Windows Server 2003	280	660

Tests with HP servers, 2 Xeon 2.4GHz, 2MB L2 Cache, 4GB RAM. The maximum number of clients is calculated when response time falls by 10% from the original.

Source: "Windows Server 2003 Terminal Server Capacity and Scaling", Microsoft, June 2003, <http://download.microsoft.com/download/5/8/c/58ccf087-33c1-41b2-bb74-fe20be37fde6/TermServScaling.doc>.

To some degree, Windows Server 2003 can get around the 4GB ceiling by enabling Physical Address Extension (PAE) mode, which allows access to physical memory beyond the 4 GB space accessible through normal 32-bit addressing. Nonetheless, a single application is still limited to only addressing 2 GB of memory. For this reason, it is better to use 64 bit processors and a 64 bit operating system for your Terminal Server, because they can address up to 18.4 exabytes and process more efficiently than 32 bit processors. Microsoft sells a 64 bit version of Windows Server 2003, and almost all GNU/Linux distributions come in 64 bit versions as well.

2.4.1. Checking CPU and memory usage

Before taking the expensive step of upgrading your hardware, first check to see whether the server's CPU is really the bottleneck. On Windows systems, open the **Windows Task Manager** by pressing Ctrl + Alt + Del simultaneously and click on the **Performance** tab to see what percentage of the CPU is being used. On Linux systems using GNOME, the Task Manager can be found under the **System** menu. Generally your system should run at 20% to 30% CPU usage under a normal load. When under heavy usage an occasional spike over 90% is not a problem. If the CPU usage averages over 50%, then your network probably needs more CPU processing power.

Often it is the case that one program can hog all the memory in the server. Check to see how much of the CPU each program is using. Look under the **Processes** tab in the **Windows Task Manager**. If using a GNU/Linux terminal, CPU usage for each program can be checked with the **proc** command. You may want to limit the use of particular applications if they prove to be memory hogs. You may want to uninstall multimedia applications and games, since they can use exorbitant amounts processing power and often don't perform well over a thin client network anyway.

Another potential bottleneck is the lack of memory in the server. Check in the **Windows Task Manager** whether your server has enough free physical memory. In a GNU/Linux terminal, memory usage can be checked with the **free** and **top** commands, although **exmap** is more reliable. If the memory is maxed out, consider installing more sticks of RAM in your server. Remember to only buy higher quality RAM, since flaky RAM chips can cause unexpected problems which are

difficult to diagnose. It is not necessary to buy overpriced RAM for overclockers, but look for the faster standard speeds. If your server's motherboard supports it, buy ECC RAM for error correction.

At a certain point, upgrading processors and RAM in your existing server becomes prohibitively expensive and adds little extra performance. Rather than continually upgrading, it is cheaper and more efficient to add additional servers to the network. Adding servers to the network has steady marginal returns, so it makes more sense than adding more processors to a single server which has diminishing marginal returns.

2.4.2. Network load balancing

In order for the processing to be evenly distributed among the available servers, network load balancing software needs to be installed. Windows 2000 Server (except for the Standard Edition) and Windows Server 2003 (all editions) have a Network Load Balancing (NLB) option built-in, so that up to 32 servers can be added to a network. Unfortunately, Microsoft's load balancing software is based on a simple *round robin* formula which simply assigns terminal sessions to any servers which are functioning, but does not try and calculate the resources available on each server. If using Microsoft's load balancing, it is recommended that all the servers have the same hardware and software configuration because the load balancer will assign an equal number of terminal sessions to each machine.²¹ Unfortunately, Microsoft doesn't not seem to have any plans to improve its load balancing in the forthcoming Windows Server 2008.²² In addition, you may want to plan your network load beforehand using Microsoft's Terminal Services Scalability Planning Tools (TSScaling), which is a suite of tools that simulate loads on networks to help plan the needed capacity of your terminal server.²³

If planning to implement a server farm, it is best to avoid using Windows 2000 Server, because it does not allow sessions to be tracked. If disconnected, the user might not be reconnected to the same server. Windows Server 2003 solves this problem with the *session directory* which allows users to reconnect to their previous session.²⁴

Citrix Presentation Server (formerly called Metaframe) provides much better load balancing than Windows Server 2003. Presentation Server's "Smart Access" feature controls how users can access applications from different locations and grants access based on various different factors. It allows the load balancing to be configured based upon 11 different performance counters. In addition, Citrix also sells Global Load Balancing software, but it is very expensive with pricing

21 Cláudio Rodrigues, "Load Balancing Terminal Services: All you wanted to know but were afraid to ask (Part 1)", updated 31 May 2006, <http://www.msterminalservices.org/articles/Load-Balancing-Terminal-Services-Part1.html>.

22 Deb Shinder, "Create a scalable thin client solution with Terminal Server farms", Tech Republic, 18 Sep 2006, http://articles.techrepublic.com.com/5100-10879_11-6116648.html.

23 For a description of the various tools in TSScaling, see "Windows Server 2003 Terminal Server Capacity and Scaling", Microsoft, Jun 2003, p. 6-7, <http://download.microsoft.com/download/5/8/c/58ccf087-33c1-41b2-bb74-fe20be37fde6/TermServScaling.doc>.

24 "Setting Up Network Load Balancing on Windows 2000 Advanced Server", 19 Apr 2003, <http://www.netadmintools.com/art247.html>; "Using Network Load Balancing With Terminal Services", 2003-04-19, <http://www.netadmintools.com/art248.html>.

starting at \$27,499.²⁵ A better solution is to use the [Clusteresis RDP Load Balancer](#) which is completely gratis and balances the load according to available resources on the servers. It supports session reconnection, application publishing and single sign-on for users. Other options are [2X LoadBalancer](#), which costs between \$449 for 2 servers and \$1895 for up to 255 servers and [Tunnel2 Secure Terminal Server Gateway](#) which costs € 89 per client on the network. Some network administrators prefer to use hardware load balancers, such as [F5 BigIP](#) or [NTavo Appliance](#), since they don't use up any processing power on the server. This hardware tends to be very expensive and generally isn't worth the price except in special situations.²⁶

If using an LTSP network, there are a few free software options available, but none of them are well developed at this point. For LTSP 5.0 in Edubuntu/Ubuntu, a preliminary load balancer from Mind Touch Software is currently [available](#) and is reported to work, although there are plans to [improve it](#). For users of LTSP 4, the Mille-Xterm project has developed a [load balancer](#), which is being used in Canadian schools running Mandriva 2007. The code should theoretically work with any distribution of GNU/Linux. For people who don't want the fiddle with advanced setups, [dividing your thin client network between various servers](#) is probably the easiest solution.

25 “Citrix Global Load Balancing for Presentation Server Ensures Uninterrupted Access to Mission-Critical Business Applications”, Citrix press release, 23 Oct 2006, <http://www.citrix.com/English/NE/news/news.asp?newsID=38805>.

26 For a discussion of the pros and cons of the various network load balancers, see Cláudio Rodrigues, Part 2, <http://www.msternalservices.org/articles/Load-Balancing-Terminal-Services-Part2.html>.

3. Microsoft Windows thin clients

Microsoft's bread and butter has traditionally been the fully equipped PC, or the *fat client*. In the mid-1990s, many of Microsoft's competitors such as SUN and Oracle promoted thin clients as a way to dethrone the Redmond, Washington software giant. Microsoft has a long history of being blind about what is the next wave of the future, whether it be the internet, media players, or embedded operating systems. Nonetheless, Microsoft has always been smart enough grasp its failings and “borrow” technology from its competitors. Its initial forays into the field are generally duds, but Microsoft keeps throwing enough money and resources at the problem, until its products eventually dominate the market. The experts may sneer because other products are better, but Microsoft is “good enough” for most of the general public.

3.1. Windows Terminal Services

When Citrix proved in the mid-1990s that Windows could run well on thin clients, Microsoft grasped the opportunity and strong armed Citrix into cross-licensing them their technology. Microsoft's first released Terminal Services as an add-on for Windows NT 4.0 Server in 1997, but this first attempt at thin client technology was poorly designed. A server could only handle 20-30 clients and it communicated to the clients via the Remote Desktop Protocol (RDP) 4, which was very inefficient. Undaunted, Microsoft shortly released Windows 2000 Server using a much more efficient RDP 5. According to one study of transmissions between the server and clients, RDP 5 was nearly twice as efficient protocol as RDP 4.²⁷ People began adopting Microsoft's thin client technology in droves, and by January 2001, it was estimated that 59% of all thin clients were running on Microsoft's Terminal Services.²⁸

3.1.1. Windows Server 2003

Microsoft's next release, Windows Server 2003, added a number features such as console mode connections, a session directory, and local resource mapping. Windows Server 2003 uses the RDP 5.2 protocol, which is more efficient and offers more features than RDP 5.0 used in Windows 2000 Server. Windows Server 2003 allows the clients to play sound and display 24-bit true color, rather than the 8-bit color used in Windows 2000 Server which only allowed 256 possible colors. Windows Server 2003 uses memory more efficiently so more clients can run off the same server, and offers better load balancing of the processing so that up the network could scale up to thousands of thin clients. Windows Server 2003 allows up to 32 servers to run on a thin client network, which is roughly 4000 clients at 125 clients per server. In addition, Windows Server 2003 offers 128 bit encryption for secure authentication and communication over the network. Windows Server 2003 also has better support for low-bandwidth connections so Terminal

²⁷ Jason Nieh, et al. “A Comparison of Thin-Client Computing Architectures: Technical Report CUCS-022-00”, Network Computing Laboratory, Columbia University, Nov. 2000, <http://www.ncl.cs.columbia.edu/publications/cucs-022-00.pdf>.

²⁸ Paul Thurrott, “Microsoft Terminal Services is Number-1 Thin-Client Solution”, 31 Jan 2001, <http://www.windowsitpro.com/Article/ArticleID/19805/19805.html>.

Services can operate over phone lines. With a 56K modem, the screen gets five or six screen updates per second, which is adequate for tasks such as word processing and web browsing.

3.1.2. RDP 6 in Windows Server 2008 and Windows Vista clients

Microsoft's next version of its Remote Desktop Protocol, RDP 6, promises to significantly improve thin client computing. It will offer 32-bit color, screen resolutions greater than 1600x1200, multiple monitor support to spread the session across two monitors, WMI scripting of terminal services, and support for the fonts and graphics libraries used in MS Vista. Most importantly, RDP 6 will allow clients to use individual applications, rather than the whole desktop from the terminal server. This is an important feature when using hybrid clients which may use some application from the server, but also use some applications locally, especially the processing intensive ones like CAD and 3D games. The Remote Desktop server in Windows Vista Ultimate, Enterprise, and Business editions already uses RDP 6, but thin client networks in RDP 6 won't be available until the forthcoming release of Windows 2008 Server. In November 2006, Microsoft released Remote Desktop Connection 6.0, which is the client software using RDP 6. It is included by default in all versions of MS Vista. Users of Windows XP Service Pack 2 can download it from the Microsoft website with Windows Genuine Advantage validation. Unfortunately, Microsoft has made no plans to release it for older versions of Windows, so older computers won't be able to take advantage of RDP 6 features.

3.1.3. Working with older Windows machines

The beauty of Microsoft's Terminal Services is the fact that it allows an old computer running an old operating system to use a new operating system hosted on the server. So a client computer running Windows 95 can display the screen from Windows Server 2003. Essentially, a Windows 95 computer with little memory and processing power is turned into a Windows XP workstation (or in the case of a Windows 2000 Server, the client is transformed into a Windows 2000 workstation.) Of course there are practical limitations to what thin clients can do. They won't handle multimedia, 3D CAD and 3D games very well, but they will be able to do most of the word processing, data entry, web browsing, and spreadsheet tasks which are needed in businesses, governments and schools.

Given the improving development of Microsoft's Terminal Services, it is best to use Windows Server 2003 if possible. Its network management tools are significantly better than its predecessors. The version of Remote Desktop Connection which is included in Windows XP can take advantage of the advanced features of RDP 5.2, but the same terminal display program can also be downloaded and installed in older computers running Windows 95, Windows 98, Windows 98SE, Windows ME, Windows NT 4.0, and Windows 2000. Older machines can run terminals from Windows Server 2003, but the color depth may have to be turned down to 8 bits (256 colors) and the screen resolution reduced down to 800 x 600.

Extremely old thin client computers with limited memory may be better suited for using Terminal Services from Windows 2000 Server instead of Windows Server 2003. Older clients running Windows for Workgroups 3.11 or Windows NT 3.51 will need to use an older version of the Remote Desktop Connection (RDC) software, which uses the older RDP 5.0 protocol. They can't

use the new features found in Windows Server 2003, since it is based upon the RDP 5.2 protocol. Remote Desktop Connection for RDP 5.0 is not available for download from the Microsoft website, but it can be found on the Windows 2000 Server installation CD.

In La Paz, a secretary training school runs a hundred 486 thin clients with Windows 2000 Server. The 486s which are mainly used to run MS-Word and teach typing have acceptable performance because their memory is topped up to 64MB. In order to facilitate administration and speed up the network, all the old NICs were replaced with the same brand of 10/100BaseT NIC. The network administrator at the school commented that Windows 2000 Server's Terminal Services run better on his 486s than later versions of Terminal Services.

3.2. Alternatives to Windows Server 2000/2003/2008

If thinking about implementing Windows Terminal Services, it is recommended to also investigate Citrix Presentation Server, formerly known as MetaFrame Server. Citrix's thin client technology is considered better than Windows Terminal Services, and is often used by larger enterprises. Citrix boasts more than 100,000 customers worldwide, including 90 percent of the Fortune 500 companies. Citrix Presentation Server is more scalable, allowing more servers per network and better load balancing to share the processing load among the available servers. Plus, Citrix offers better software to manage server farms, so that each server maintains the same configuration. In addition, Citrix has long been able to operate in a mixed environment on PCs, Macs, and UNIX/Linux, whereas Microsoft's Terminal Services only work with PCs and Macs (and the software for Macs is slightly outdated as well).

Citrix has taken client computing a step farther, blurring the line between thin and fat clients with Presentation Server 4.5. Citrix's latest version of Presentation Server allows the thin clients to cache Windows DLL (dynamic link libraries) and other files needed to run applications on their local harddrive. This caching allows applications to continue running even when the network dies. More importantly, processing intensive streams can be passed to the clients. Streaming and local processing provides better multimedia capabilities (although it also requires higher-end clients).²⁹ Unfortunately, Citrix doesn't market its software for mainstream use. Its prices aren't listed online and are only available by contacting the company or its authorized resellers. In other words, Citrix is only recommended for governments and businesses which have substantial ICT budgets.

3.2.1. 2X ThinClientServer

If your budget is limited and you want to avoid restrictive licenses, consider using 2X ThinClientServer. For people who don't need tech support, 2X offers the PXES Edition, which is gratis and includes some FLOSS (free/libre/open source software). 2X provides an online forum in English where you can ask questions and search for solutions. For people who want tech support and a few extra features such as support for Citrix's ICA protocol, 2X offers the normal edition of ThinClientServer which is cheaper than Citrix's and Microsoft's thin client software.

²⁹ For a review of Citrix Presentation Server 4.5, see: Michael Fudge Jr., "Rollout: Citrix Presentation Server 4.5", 19 Mar 2007, <http://www.networkcomputing.com/channels/netsysmanagement/showArticle.jhtml?articleID=198000859>.

With ThinClientServer, thin clients with 64MB RAM or more can network boot from the server, so no discs are needed in the thin clients. Not only does this save on hardware and administration costs, but it also means that none of the thin clients need operating system and client access licenses like with Windows Terminal Services and Citrix. Since 2X ThinClientServer can be installed in Windows 2000 or Windows XP and includes a DHCP and TFTP server, you don't need to pay for an expensive operating system license on your server. If you want to create hybrid clients that run some programs locally and some from the server, ThinClientServer can also be used with disked thin clients with 32MB RAM or more. ThinClientServer has web-based management tools, so the thin client network can be easily administered from any client computer or via the internet.

If you are thinking about switching to GNU/Linux in the future, 2X ThinClientServer is a good choice because 2X offers TerminalServer for GNU/Linux, which is very similar to ThinClientServer for Windows. The transition will be much smoother with 2X's thin client software, since their web-based management tools are almost identical and more user-friendly than the text-based tools for LTSP, DRBL and VNC.

3.3. Installation Requirements for Windows 2000 Server and Windows Server 2003

Microsoft lists extremely low minimum requirements for installing Windows 2000 and 2003 Server.

Hardware requirements for Microsoft Windows Server 2000/2003

OS	Edition	CPU	Minimum	Recommended	Maximum*
Windows Server 2003 R2	Standard Edition	x86	133MHz CPU, 128MB RAM, 2.9GB HD, VGA	550MHz CPU, 256MB RAM, SVGA (800x600)	4GB RAM, up to 4 processors
	Enterprise Edition	x86	133MHz CPU, 128MB RAM, 2.9GB HD, VGA	733MHz CPU, 256MB RAM, SVGA (800x600)	64GB RAM, up to 8 processors
		x64 or ia64	733MHz CPU, 128MB RAM, 2.9GB HD, VGA	733MHz CPU, 256MB RAM, SVGA (800x600)	2TB RAM, up to 8 processors
	Datacenter Edition	x86	400MHz CPU, 512MB RAM, 2.9GB HD	733MHz CPU, 1GB RAM	128GB RAM, 8 – 32 processors
		x64 or ia64	733MHz CPU, 512MB RAM, 2.9GB HD	733MHz CPU, 1GB RAM	2TB RAM, 8 – 64 processors
Windows Small Business Server 2003 R2	Standard Edition	x86	750MHz CPU, 512MB RAM, 16GB HD, VGA video, 1 NIC	1GHz CPU, 1GB RAM, SVGA (800x600), 2 NICs	4GB RAM, up to 2 processors, up to 75 clients
	Premium Edition	x86	750MHz CPU, 512MB RAM, 16GB harddrive, VGA video, 1 NIC	1GHz CPU, 1GB RAM, 16GB harddrive, SVGA (1024x768), 2 NICs	4GB RAM, up to 2 processors, up to 75 clients
Windows Server 2003	Standard Edition	x86	133MHz CPU, 128MB RAM, 1.25-2.0GB HD, VGA	550MHz CPU, 256MB RAM, SVGA (800x600)	4GB RAM, up to 4 processors

	Enterprise Edition	x86	133MHz CPU, 128MB RAM, 1.5GB HD, VGA	733MHz CPU, 256MB RAM, SVGA (800x600)	32GB RAM, up to 8 processors
		x64 or ia64	733MHz CPU, 128MB RAM, 2.0GB HD, VGA	733MHz CPU, 256MB RAM, SVGA (800x600)	64GB RAM, up to 8 processors
	Datacenter Edition	x86	400MHz CPU, 512MB RAM, 1.5GB HD	733MHz CPU, 1GB RAM	128GB RAM, 8 – 32 processors
		x64 or ia64	733MHz CPU, 512MB RAM, 2.0GB HD	733MHz CPU, 1GB RAM	2TB RAM, 8 – 64 processors
Windows 2000 Server	Standard		133MHz CPU, 128MB RAM, 2GB HD	256MB RAM	4GB RAM, up to 4 processors
	Advanced		133MHz CPU, 128MB RAM, 2GB HD	256MB RAM	8GB RAM, up to 8 processors
	Datacenter	ia64	Pentium III Xeon, 256MB RAM, 2GB HD		64GB RAM, 8-32 processors

* Number of processors per server. A dual core processor counts as one processor.

Source:³⁰

Obviously Microsoft's minimum and recommended requirements are only good enough for installing Windows 2003 and 2000 Server, but not enough to consider running the Terminal Services and handling the processing needs of the clients. If planning to set up a thin client server with Microsoft's Terminal Services, a study by HP and Microsoft provides test results of how many thin clients can run on Xeon servers using Windows Server 2003:

Server Configuration	HP Server Model	Knowledge Worker	Data Entry Worker
4 x Intel Xeon Processors MP 2.4GHz, 2MB L2 Cache, 4GB RAM	DL560	270 Users*	520 Users
2 x Intel Xeon Processors 2.4GHz, 2MB L2 Cache, 4GB RAM	DL360G3	200 Users	440 Users
1 x Intel Xeon 4 Processor 2.4GHz, 2MB L2 Cache, 4GB RAM	DL360 G3	140 Users	200 Users
1 x Intel Ultra Low Voltage Pentium III 900 MHz, 1GB RAM	BL10e	50 Users	120 Users
4 x Intel Xeon Processors MP 2.0 GHz, 2MB L2 Cache, 4GB RAM	BL40p	240 Users	Not Tested
2 x Pentium III Xeon 550 MHz, 2MB L2 Cache, 4GB RAM	ProLiant 6400R	170 Users	Not Tested

* Using Physical Address Extension and 6GB RAM.

Fuente: “Windows Server 2003 Terminal Server Capacity and Scaling”, Microsoft, Jun 2003, <http://download.microsoft.com/download/5/8/c/58ccf087-33c1-41b2-bb74-fe20be37fde6/TermServScaling.doc>.

The “data entry workers” in the study were only using Excel and only required 3.5 MB of RAM in the server for each additional client computer. In contrast, the “knowledge workers” were using Word, Excel, Internet Explorer, and Outlook concurrently and multitasking between the programs.

³⁰ “System Requirements”, 13 Mar 2007, <http://technet.microsoft.com/en-us/windowsserver/bb430827.aspx>, <http://www.microsoft.com/Windowsserver2003/sbs/evaluation/sysreqs/default.msp>, “Graphical Windows 2000 Guide Version 0.6.0 Oct 23, 2001”, <http://www.comptechdoc.org/os/windows/win2kgraph/>, “Windows 2000 Minimum Specifications and Requirements”, <http://www.windows2000.windowsreinstall.com/specs.htm>.

For these “knowledge workers” the server only required 9.5 MB of RAM per client. These numbers are impressive, but remember that these tests are only relevant for highly structured environments where only a limited number of programs are being used. In a normal environment where people could be running 10-15 different programs and some of those programs are memory hogs, the servers would need significantly more resources per client. Microsoft recommends 10 MB of extra RAM in the server for each additional client which will only be running one program at a time. If the client will be running multiple programs, Microsoft recommends 21MB per client. In a typical environment, people will probably be running programs like Photoshop and Windows Media Player which can use significantly more memory than the standard office applications, so even more RAM will be needed.

For imaging intensive applications, NexTech provides a more realistic estimate of the resources needed to run Windows Terminal Services with 1024x768 resolution and more demanding applications:

NexTech's recommendations for servers using Windows Terminal Services

	Recommended in server	Minimum Required
Operating System	Windows Server 2003 with Terminal Services Client Access Licenses for each client	Windows 2000 Server with Terminal Services Client Access Licenses for each client
MS Office	MS Office 2003 or newer	MS Office 2000
CPU	Dual Pentium 2.5+ GHz	1.5+ GHz Pentium
RAM	1GB + 128MB per client	512MB + 64MB per client SDRAM
Hard Disk	500+ GB, RAID (if budget allows)	80+ GB

Source: “Practice 2008 Terminal Server Configuration - Hardware Recommendations”,
<http://www.nextech.com/index.asp?TermServSpec.htm>.

It is best to avoid older 16bit software, because it takes more memory to run it on 32bit operating systems like Windows Server 2003. Older software applications written before the advent of Windows 2000 Server should also be avoided if possible since they generally weren't designed to be compatible with Terminal Services. If you plan on using older software check [this list](#) for compatibility and read [these recommendations](#) for using older applications. Be prepared to implement special work-arounds to get some software running. Citrix software suffers similar problems with incompatible software. One commentator on an online forum explained:

The difference between a Citrix implementation failing, and working successfully is knowing the technology that you're working with. You can't have an application that[']s going to go rouge and take down your server with 50 users on it -- and that is where most implementations fail. Every application can not be made to work in a thin environment.³¹

If you plan on implementing a Windows thin client network, you will need to carefully test each software application to see whether it works correctly over the network. Unexpected problems can arise when files aren't found in the local harddrive where programs expect them to be. In addition, software applications should be installed *after* Windows Terminal Services are enabled, because some applications install differently in a terminal server.

³¹ <http://ask.slashdot.org/comments.pl?sid=223912&threshold=1&commentsort=0&mode=thread&pid=18129940#18130160>.

3.4. Thin client requirements

The thin client network will have more advanced functionality if the clients are running Windows XP or Windows CE when using Terminal Services from Windows Server 2003. Nonetheless, the clients can function with Windows 95, Windows 98, Windows NT 4.0, Windows ME, and Windows 2000 as well. The advantage of using old operating systems on the clients is they function well on machines which have little memory and slower processors. Plus, you aren't forced to pay for expensive upgrade licenses from Microsoft.

If using Windows 2000 Server, each client computer is legally obligated to have an operating system license, a Terminal Services Client Access License (CAL), and a Windows 2000 Server CAL. Each copy of Windows 2000 Professional includes a Terminal Services CAL, but not a Windows 2000 Server CAL. Earlier versions of Windows do not include a Terminal Services CAL, so you will have to purchase a Terminal Services CAL and Windows 2000 Server CAL for each client.³²

Beginning with Windows Server 2003, Microsoft initiated a new 'per user' license to add to the already familiar 'per device' license. Each client must legally have a Terminal Services Device CAL *or* a Terminal Service User CAL. In addition each client needs a Windows Server Client Access License and an operating system license. You can avoid paying for an operating system by making diskless thin clients with a program such as [ThinStation](#) or [PXES Universal Linux Thin Client](#). See section [3.9. Windows Diskless Thin Clients](#).³³

Minimum Requirements for Microsoft client operating systems

Operating System	Release Date	CPU Type	Processor (Mhz)	RAM (MB)	Harddrive (MB)	Video
Windows 3.1	6 abr 1992	80386	16	2	8	VGA
Windows 95	24 jun 1995	80386DX	16	4	35	VGA
Windows 98	25 jun 1998	80486DX	66	16	195	VGA
Windows 98SE	9 may 1999	80486DX	66	24	205	VGA
Windows ME	14 sep 2000	Pentium I	150	32	270	VGA
Windows XP	25 oct 2001	Pentium II	233	64	1500	SVGA
Windows Vista	30 ene 2007	Pentium IV	1024	512	15000	SVGA, 32MB RAM

Source: <http://w iki.oldsos.org/Dos/OriginOfDos>; <http://w w w .upenn.edu/computing/printout/archive/v08/2/w indow s.html>; <http://w w w .computerhope.com>; <http://w w w .microsoft.com>

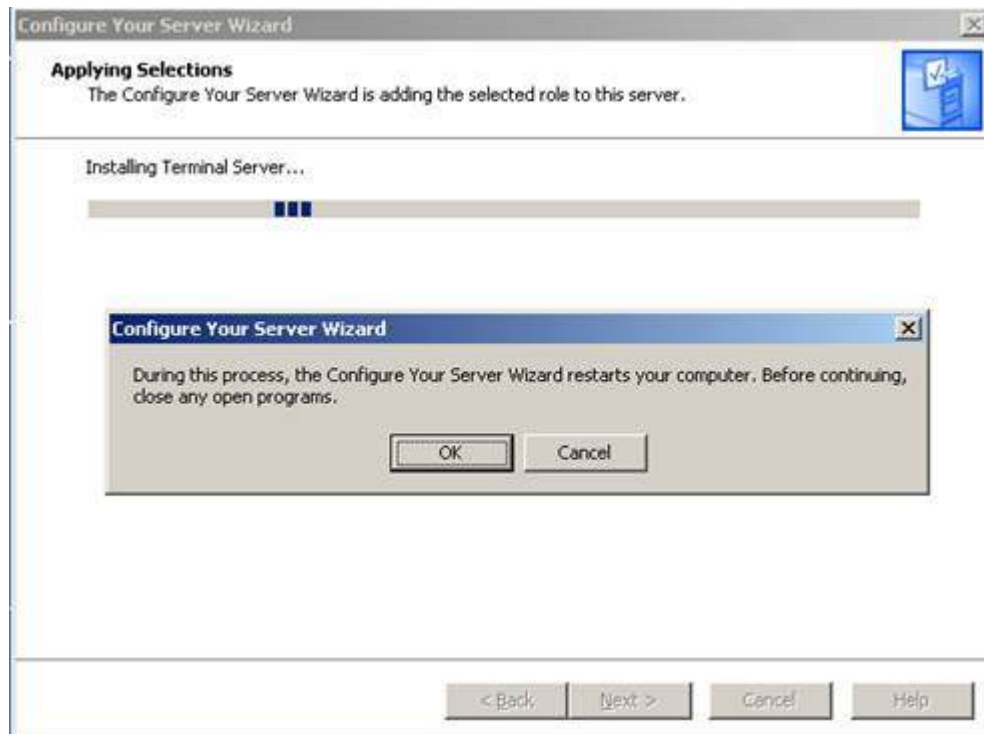
3.5. Setting up Terminal Services in Windows Server 2003

Assuming that Windows Server 2003 is already installed on the server, go to **Administrative Tools** under the **Start** menu. Select the “**Configure your server**” wizard. In the select a role section, choose “**Terminal Server**” and click “**Next**” twice to confirm. The wizard will then start

³² License requirements in Spanish: “Se necesitan licencias para utilizar software cliente de Servicios de Terminal Server”, 22 Feb 2000, <http://support.microsoft.com/kb/244749>; In English: “Windows 2000 Terminal Services: An Integrated, Server-Based Computing Solution”, updated 9 Jun 2001, <http://www.microsoft.com/technet/prodtechnol/win2kts/evaluate/featfunc/tssol.mspix>.

³³ “Windows Server 2003 Terminal Server licensing issues and requirements for deployment”, <http://support.microsoft.com/?scid=kb%3Ben-us%3B823313&x=13&y=11>.

to install the required files and warn you that the machine will have to be restarted during the installation process. Close any open programs and click “OK”.



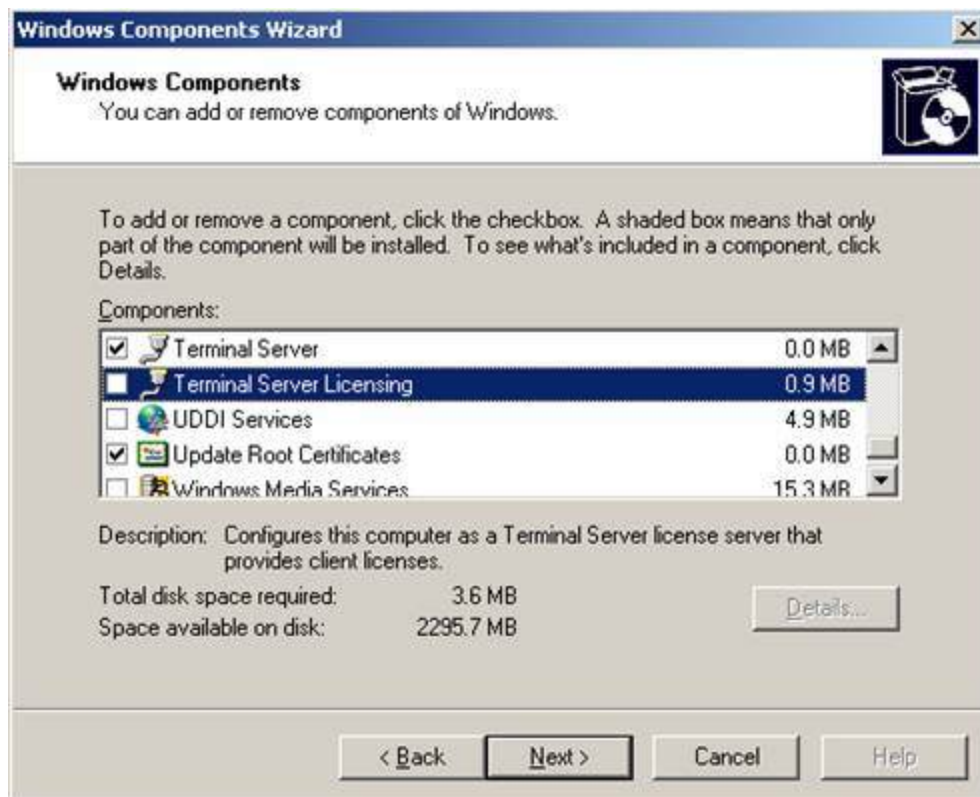
The installation will continue for several minutes, then the computer will reboot. After restarting, and you log back in, a confirmation screen will appear that states that the computer is now a terminal server.



3.5.1. Licensing

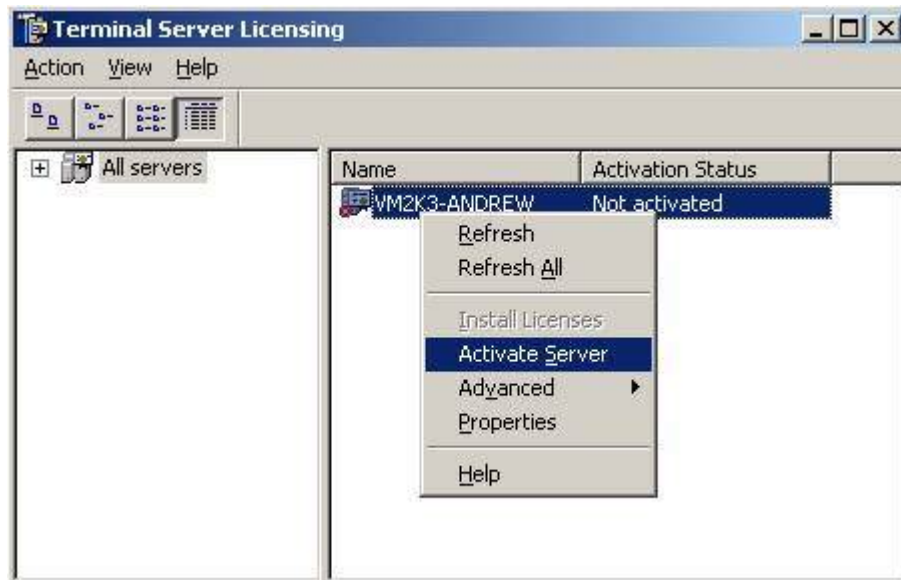
You will be given a 120 day evaluation period to use unlicensed clients with Microsoft's Terminal Services. After 120 days, the clients will not be able to initiate a session and use Terminal Services.

In order for the licensing to take effect, Terminal Server Licensing will have to be installed on your machine. Go to the “Add/Remove” window in the Control Panel and find the “Windows Components Wizard” section. Click on “Terminal Server Licensing” and follow the installation instructions.



Once Terminal Server Licensing is installed, your server will be listed in the Terminal Server Licensing console. Now your server will need to be activated before it can start distributing CALs. Activation can be done via a direct connection to the internet, a web browser, or over the telephone.

To begin the activation process, right click on your server in the Terminal Server Licensing console and select “Activate Server”:



The wizard will ask you to enter your personal details and selection options for your server. Follow the wizard's instructions and click on "Finish" when done.

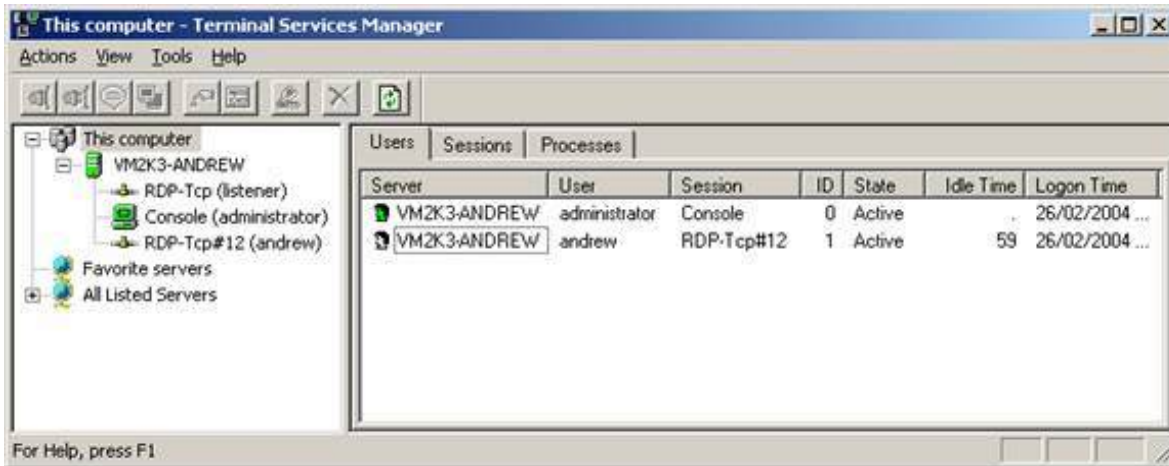
3.6. Configuring the Terminal Server

The administrative tools to configure the Terminal Server are found in the **Administrative Tools** folder in the **Control Panel**:

- Terminal Services Manager
- Terminal Services Configuration

3.6.1. Terminal Services Manager

The Terminal Services Manager was redesigned for the Windows Server 2003 and is significantly better than the manager found in Windows 2000 Server. Click on the server name to view and manage the Users, Sessions or Processes on each server. Green icons indicate which servers are online. If the servers are disconnected, it should have a gray icon.



Go to the “**Users**” tab to see who is connected, how long they have been connected, and the state of their connection. You can view the status of a user, disconnect a user, and reset or logout a user's session by right clicking a user's name and selecting an option from the menu. You can also send the user a message which will be displayed as a pop-up message on the client machine.

To view or control the terminal server sessions, go to the “**Sessions**” tab. Right click on a session and select the status to see the incoming and outgoing data or reset the session.

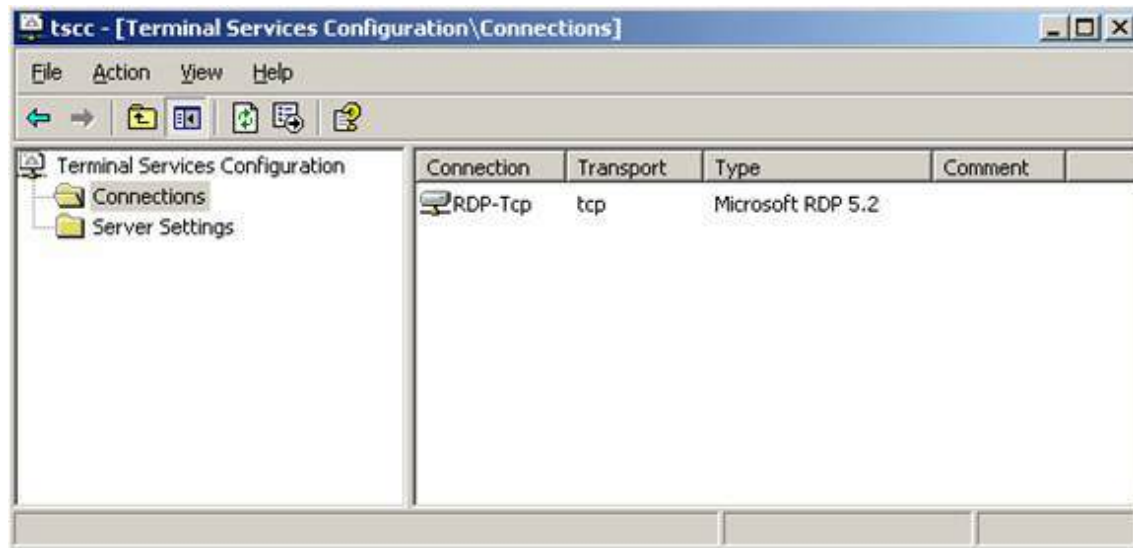
The “**Processes**” tab shows all the running processes and which user they belong to. This is a simplified version of the “Processes” tab found in the Windows Task Manager. To kill a process, select a user, right click and select “End process”.

Each time that a user opens a new process, the number attached to the end of the username will change. For example, in the example above the username is listed as “FDP-Tcp#12”, but “12” will only last for this session. Click on a username to view its processes and session information.

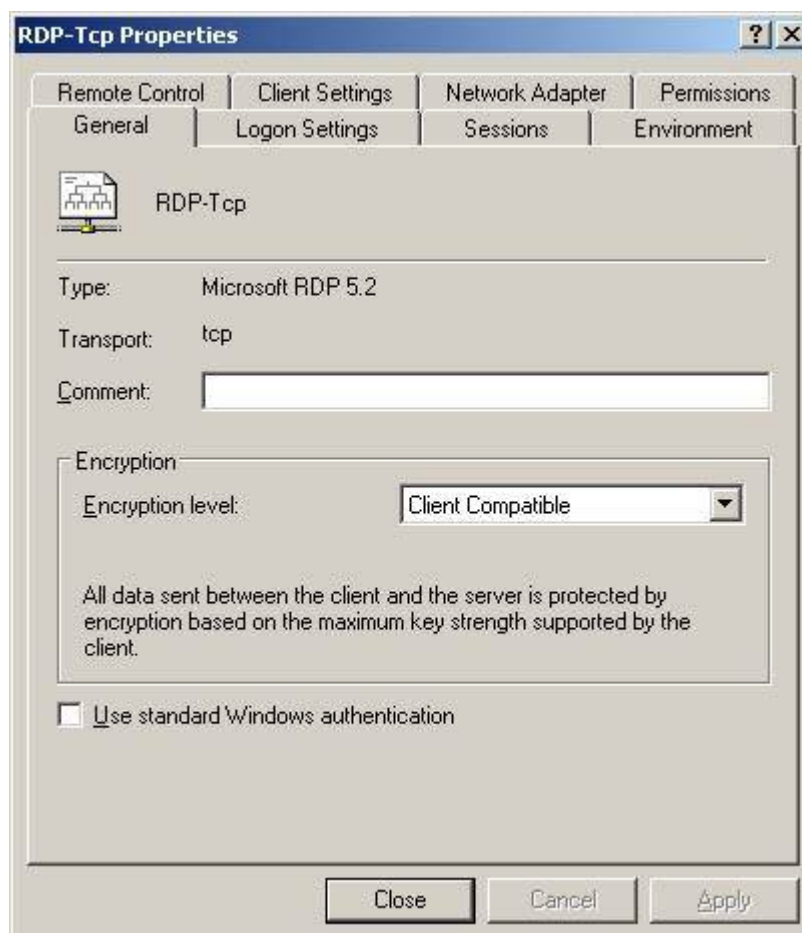
It can be useful to add your servers to the “favorite servers” list, so they are easier to find. Right click on a server and select “Add to favorites”

2.6.1.1. Terminal Services Configuration

The Terminal Services Configuration window is used to set the properties for connections and servers.



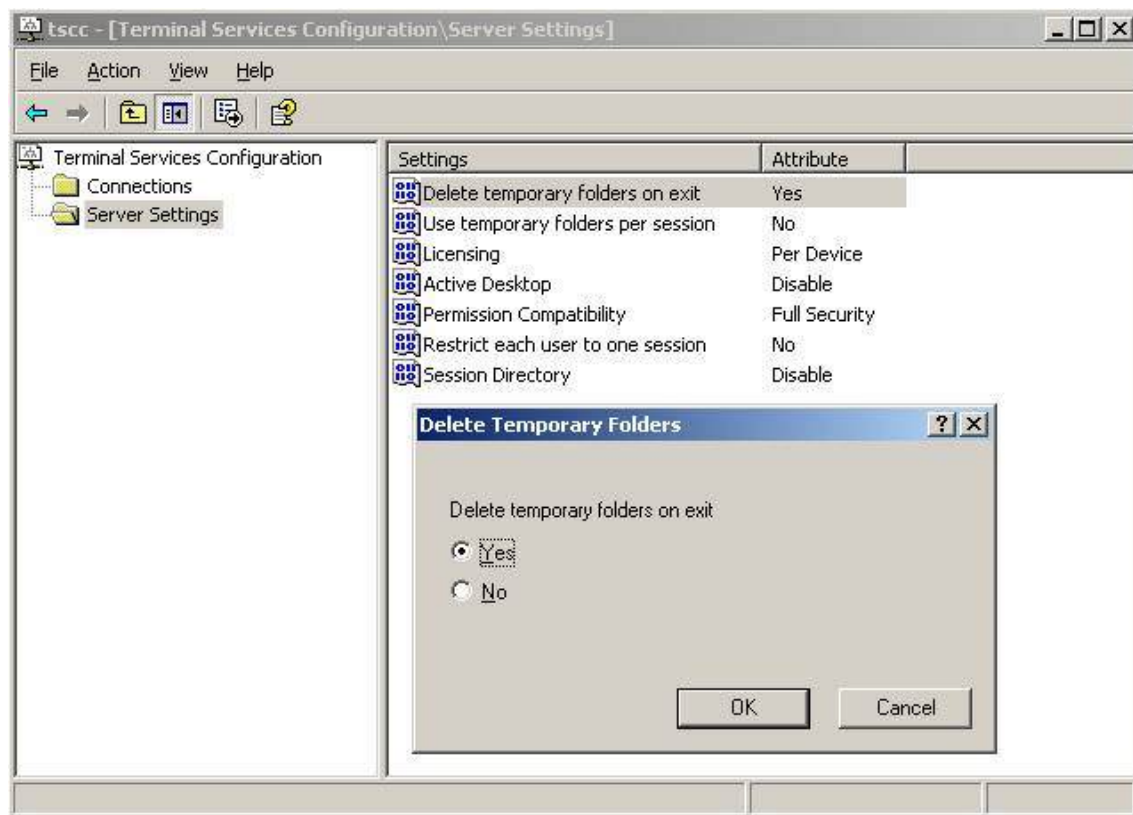
In the Terminal Services Configuration window, you can see any connections which have been created. To set its properties, double click on a connection.



The following table describe what actions can be done in each tab of the **Properties** window.

Tab	Description
General	Add a comment, change the encryption level, enable standard windows authentication.
Logon Settings	Select whether or not to always use the same credentials for logging on, enable “Always prompt for password”.
Sessions	Select whether to override the user’s settings with a set of predefined settings.
Environment	Choose to override settings of a user profile and run a program when the user logs on.
Remote Control	Change the way the remote control facility is used, disable remote control.
Client Settings	Change connection, color and mappings settings.
Network Adapter	Specify the type of network adapter you want to use and change the connection limit.
Permissions	Specify the user permissions (who has access to the terminal server and who doesn’t).

The Terminal Services Configuration window contains a the “Server settings” section, which allows you to modify the properties of the servers. Double click a setting on the list to change a setting.



Using these tools, you can effectively manage the machines and the users in your thin client

network.

3.7. Using Terminal Services in the Client

A Windows 2003 Terminal Server can be accessed by a Windows client that has Remote Desktop Connection installed or via a web browser with Remote Desktop Web Connection.

3.7.1. Remote Desktop Connection (RDC)

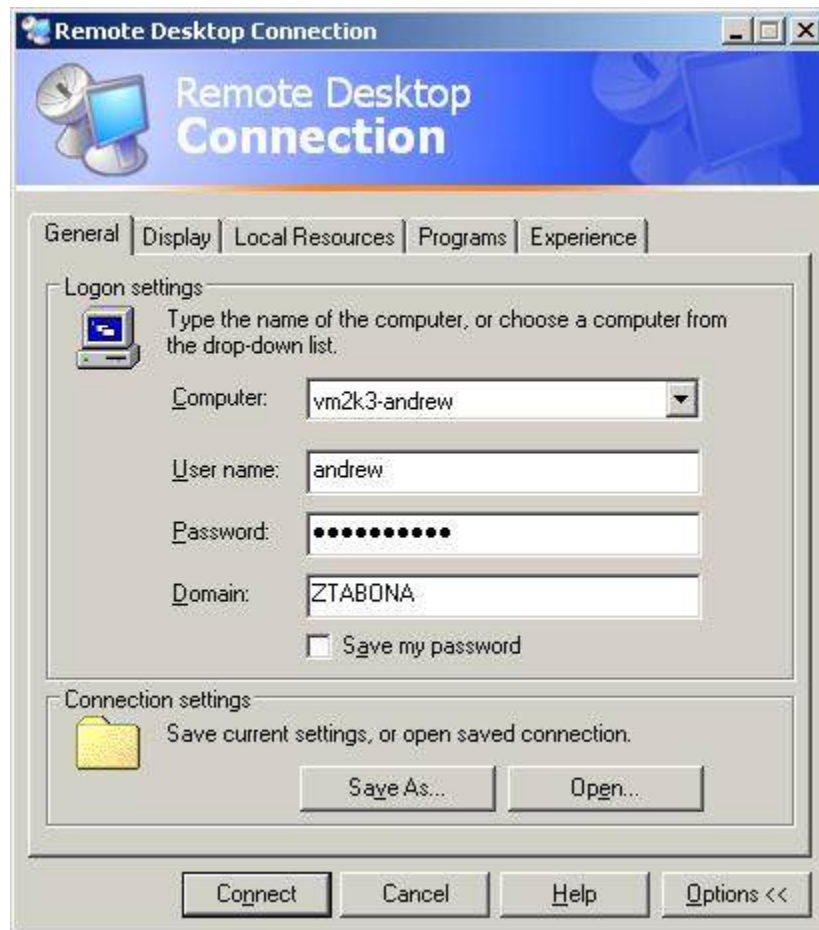
Remote Desktop Connection, which is also referred to as the Terminal Services Client, is installed by default on Windows XP and Windows Vista. If you have Windows XP Service Pack 2, you can download Remote Desktop Connection 6.0 [here](#) and install it. For Windows XP Service Pack 1 or older version of Windows, download RDC 5.2 [here](#) and install it. If you don't have access to the internet, you can also find the RDC software on the Windows XP installation CD. Insert the CD and select "Perform additional tasks" in the autorun window that pops up. Choose the option to install the Remote Desktop Connection. If you need to install Remote Desktop Connection on Windows for Workgroups 3.11 or Windows NT 3.51, it is no longer available for download, but you can find the software on the Windows 2000 Server installation CD.

If you have a Macintosh, download the Remote Desktop Connection Client 1.0.3 from [here](#). Unfortunately, the Mac client software is only available in English, German, Japanese, and French, so Latin American users have to select one of those languages.

Microsoft does not make client software for UNIX and GNU/Linux, but the free software program [rdesktop](#) can be used to connect to Windows Terminal Services on UNIX/Linux machines. To install rdesktop, it is best to download it from the repository of your distribution. Otherwise, you will have to download the source code and compile it. If using rdesktop, think about also installing tsclient (Terminal Server Client), which is a GUI front end in GNOME for several different terminal clients (rdesktop, Xnest, and VNC). It is included in Ubuntu/Edubuntu by default.

Once RDC is installed, it can be run in Windows XP by going to **Start > All Programs > Accessories > Communications > Remote Desktop Connection**.

By default, the Remote Desktop Connection window only shows a drop-down box to select the remote machine, but many more options are displayed by clicking the "**Options >>**" button:



In the **General** tab you can enter the computer, username, password and domain. If you want to save your connection settings for future use, click on the “Save As” button. The other tabs are used for performance related options like the display size and color, speed and placement of resources.

Once you have entered the correct logon details, press “**Connect**” to initiate the session. You may have to reenter the logon details a second time (unless that option has been disabled from the terminal server).

3.7.2. Using the command line

If you would rather login from the command line, you can enter the command:

```
mstsc -v:servername /F -console
```

The option **-v** specifies which server to connect to; **/F** is for full screen mode; and **-console** indicates that you want to connect to the console.

3.7.3. Automatic logins

You can allow users to automatically logon to a session without having to type their username and password each time they initiate a connection. To do this, on the server open the Group Policy

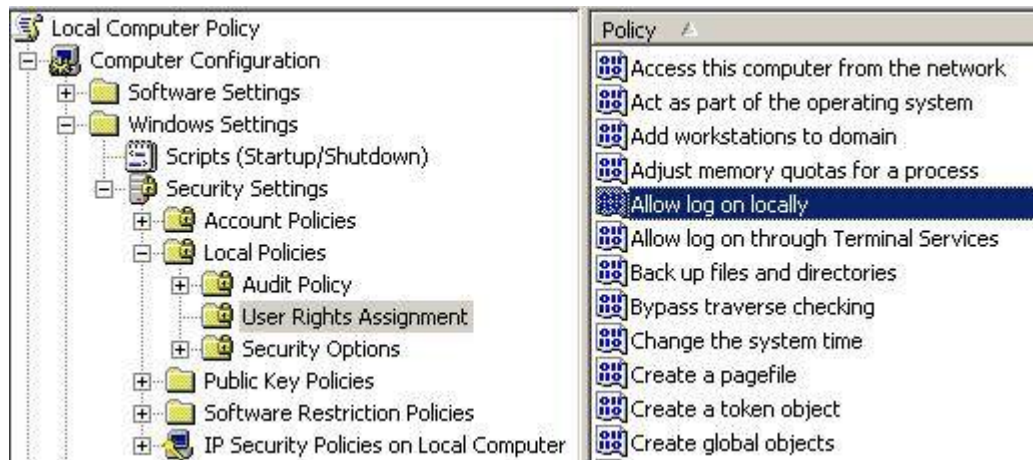
Object Editor by entering “gpedit.msc” in **Start > Run**. In the Group Policy Object Editor window, click on **Administrative Templates** and then select **Windows Components Terminal Services** and then choose **Encryption and Security**. Open the properties box of “Always prompt client for password upon connection” and disable it. Then go to the client computer and open Remote Desktop Connection. In the “General” tab enter the logon information in the appropriate boxes.

3.7.4. Fixing Login Problems

If you have trouble logging in, there are two common reasons why users have login problems.



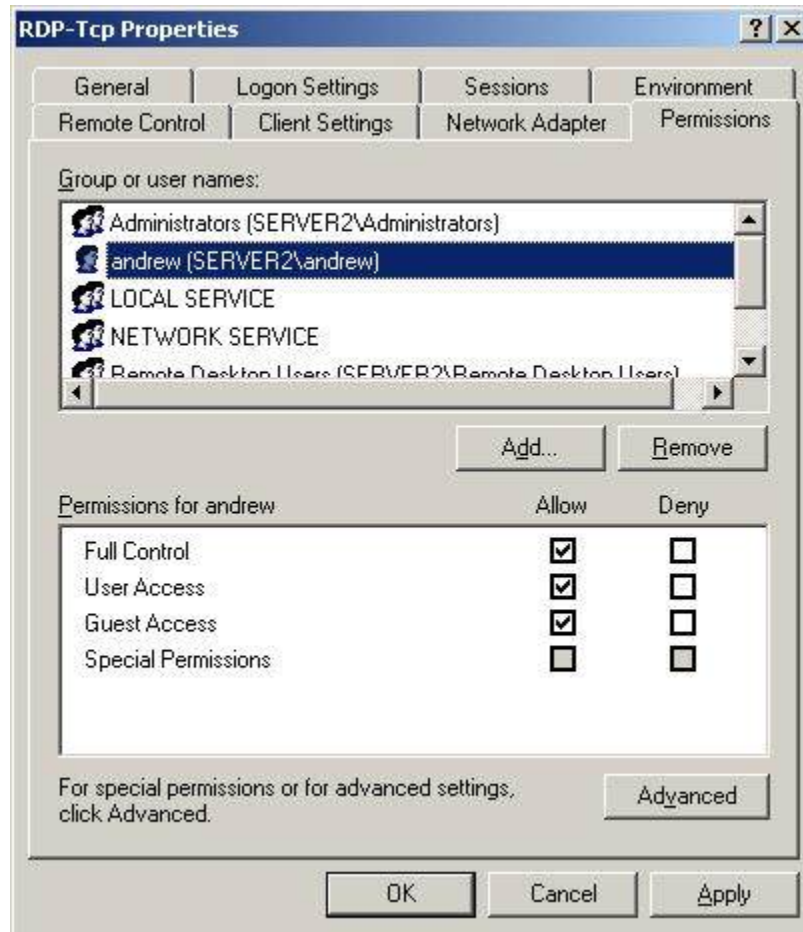
If you see the message “The local policy of this system does not permit you to logon interactively,” then the group policy of the terminal server needs to be changed so the user can logon interactively. To change the group policy, type “gpedit.msc” in the **Run** window (or in DOS). When GPEdit opens, go to **Local Computer Policy > Computer Configuration > Windows Settings > Security Settings > Local Policies > User Rights Assignment**. Double click on the “Allow Log on Locally” in the Policy list. Choose the user that will be granted local log on access and press “OK”.



Users might also encounter an error message when they try to logon which reads, “You do not have access to logon to this session”.



This message indicates that the account has not have the proper permissions assigned in the Terminal Servers Manager. To assign the needed permissions, go to your server and open the Terminal Services Configuration window. Double click the RDP connection (often called “RDP-tcp” by default) in the main window to open the Properties dialog box. Go to the “Permissions” tab and click on “Add”, then choose the user's account. Assign the correct permissions, then click “OK”. Now the user should be able to login without problems.



3.7.5. Logging off

If users just disconnect from a session or close the remote desktop window, the programs that they are using will continue to run on the server and the memory they use won't be freed up. It is important to properly log off because this will free up system resources for other users on the thin client network.

3.8. Using Terminal Services from a Web Client

The terminal services web client will allow you to logon to a terminal server from your web browser. This allows terminal services from any computer, which is especially handy when traveling or working from home. The only limitation of web client access is that low-bandwidth connections can be very slow. The RDP 5.2 protocol on Windows Server 2003 handles slow internet connections better than past RDP protocols, but don't expect rapid screen updates when connecting over a 52Kb/s modem. Internet Information Services (IIS) must be installed and configured on the terminal server.

To open a terminal hosted from the server, it is recommended that you have Internet Explorer

installed on the client machine (although it can work with other web browsers with an ActiveX plugin or Internet Explorer emulation). On the client, open the web browser and in the address bar type the following:

http://server_name/tsweb

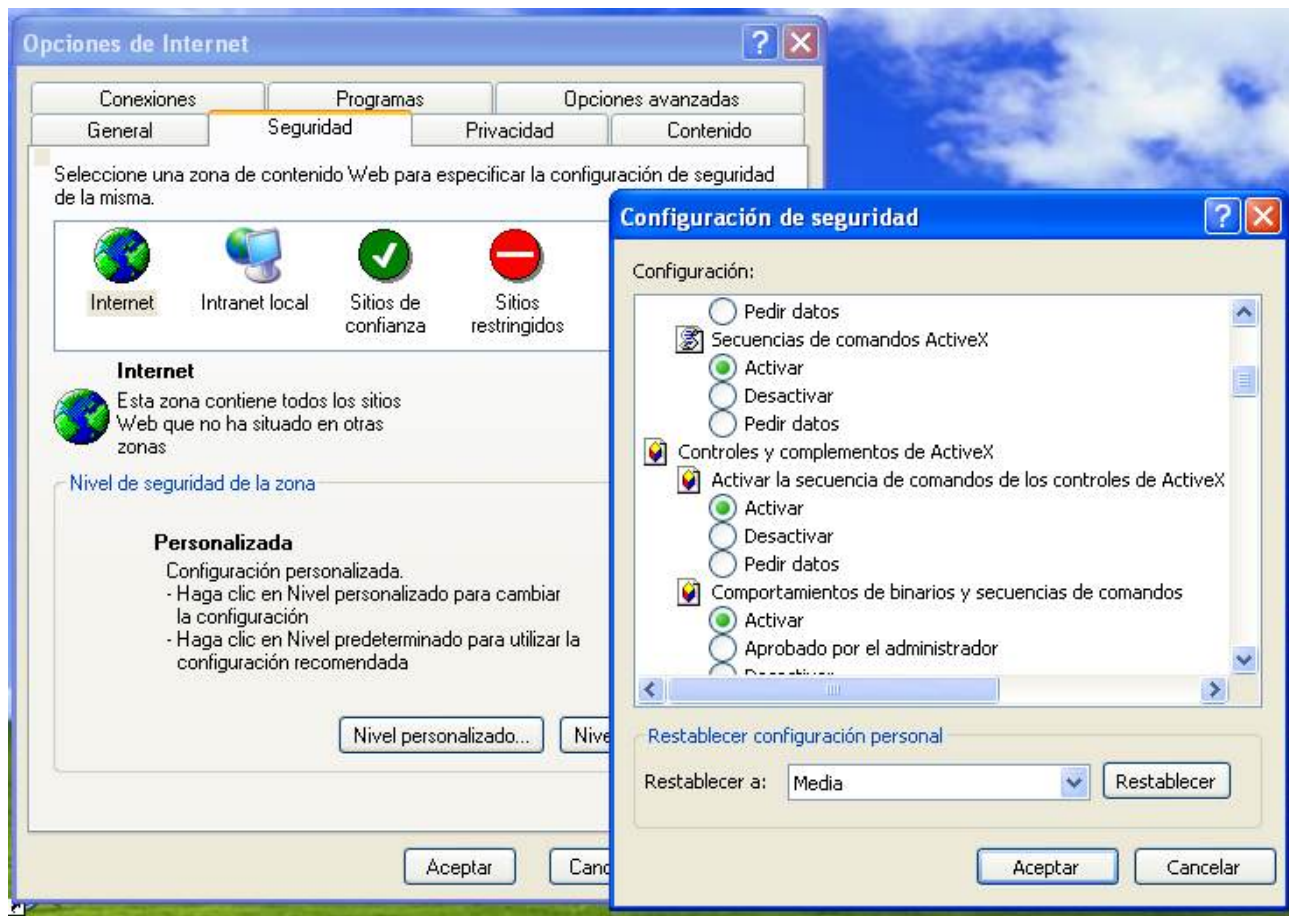
where **server_name** is the name of the terminal server or the IP address. If the WWW service and the tsweb website has been started on the server then you will see a page like the following:



Enter the name of the server that you want to connect to and choose the size of the screen before clicking “**connect**”. Unfortunately, connecting to the server requires that an ActiveX component be installed on your computer. Many web browser's have disabled ActiveX because it can be a security hazard, so you will have to enable it.

3.8.1. Enabling ActiveX with Internet Explorer

If you use Internet Explorer, Go to **Tools > Internet Options**. In the “Internet Options” window, select the “Security” tab, then select the “Internet” icon and click on “Personalized Level”. In the “Security Configuration” dialog box which appears, select “Activate” for all the options dealing with ActiveX. Then select “OK”.



3.8.2. Installing ActiveX in FireFox, SeaMonkey, Mozilla Suite, Netscape or Opera

Officially, Microsoft only supports Terminal Services over a web client in Internet Explorer. Nonetheless, you can probably get Terminal Services to work on other web browsers by installing the ActiveX plugin created by Adam Lock. Currently there is no plugin available for Mozilla FireFox 2, so use FireFox 1.5 instead. SeaMonkey 1.0 and FireFox 1.5 both use the same plugin. For more info, see <http://kb.mozillazine.org/ActiveX>. To download the plugin, go to <http://www.iol.ie/~locka/mozilla/plugin.htm#download>. Only download the plugin compiled for your version of web browser.

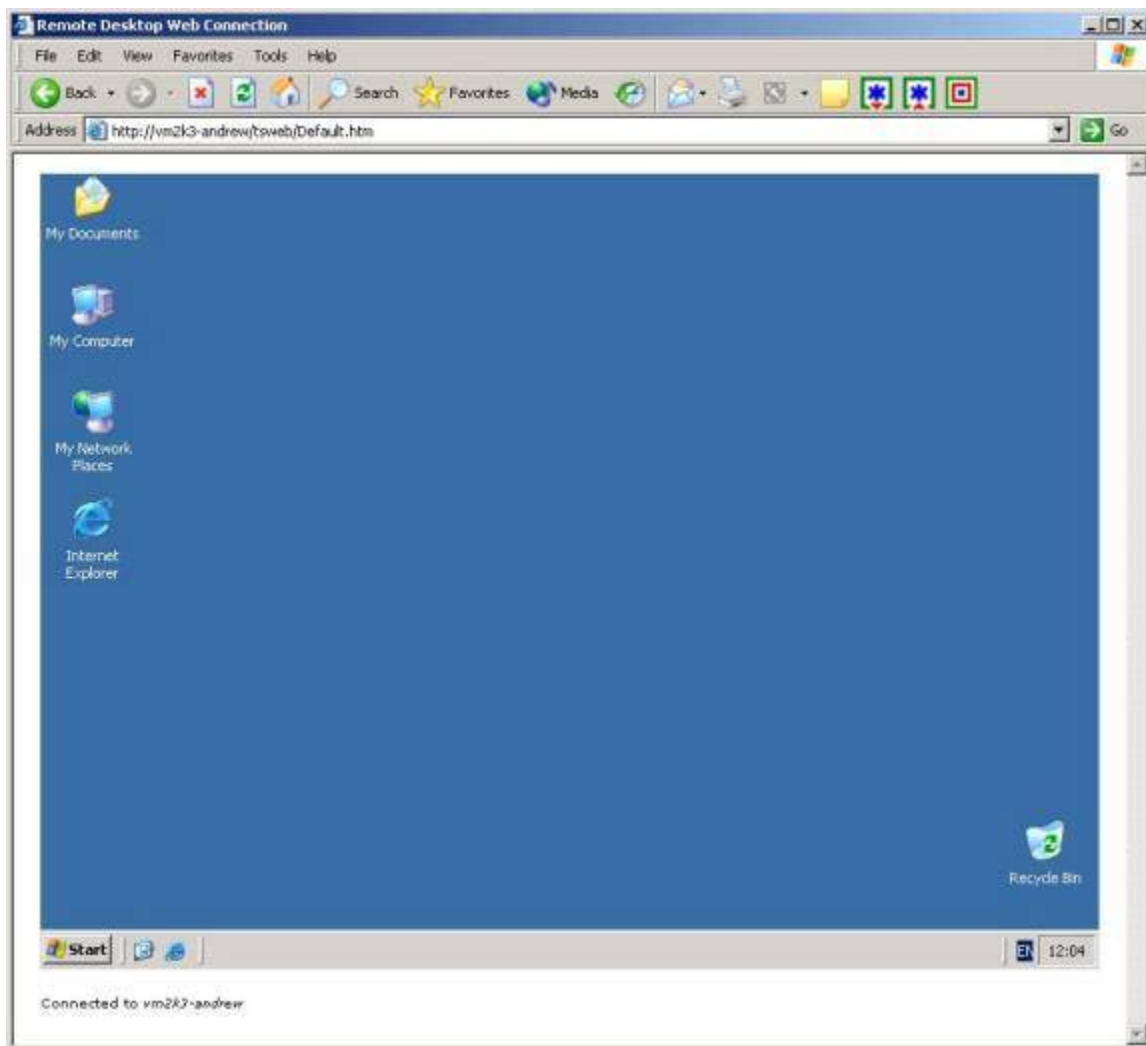
If Adam Lock's ActiveX plugin doesn't work, the other option is to install IE Tab, a plugin that embeds Internet Explorer inside a FireFox tab. For more info, see <https://addons.mozilla.org/firefox/1419/>.

Opera users can use Terminal Services by using the Neptune plugin to run the Internet Explorer engine within Opera. For more info, see <http://www.opera.com/support/search/view/415/>.

3.8.3. Logging in to a Windows Terminal with a web client

In order for the web client to connect, it needs to have an ActiveX component installed. If it isn't installed, you will be prompted to install it. Click “Yes” when the windows pops up to confirm the setup. If you have a slow internet connect or a low screen resolution on your computer, it is a good idea to select a lower screen resolution in the web client, such as 800x600 or 640x480.

Then the terminal services screen should appear inside the web browser:



3.9. Windows Diskless Thin Clients

The hardware used to be the largest expense, whereas the software was largely an afterthought. When the first PCs were selling for \$2000 in 1981, the first version of MS-

DOS cost only \$40. Today, the situation is the reverse, with software licensing often costing more than the hardware to run it. The official retail price for Windows Vista Home Basic is \$199, and Vista Ultimate costs a whopping \$399. Microsoft has been repeatedly convicted in court of holding a monopoly and using that monopoly to restrict competition, but there doesn't seem to exist the political will to reign in Microsoft's abuses.

The best way to avoid Microsoft's stranglehold is to switch to GNU/Linux, but this simply isn't feasible in some situations, and many users are reluctant to learn a whole new operating system. Nonetheless, smart network administrators are searching for ways to reduce their licensing costs. Even if using a thin client network with Windows' Terminal Services, you can still avoid paying for operating system licenses for each of the client computers with a handy program called [Thinstation](#). When the clients bootup, they connect to the server and download a tiny GNU/Linux kernel, which is loaded into the RAM. Thinstation allows thin client computers to boot up without a harddrive (or any other type of drive if they have PXE), saving on hardware costs since there are no moving parts to potentially fail. Likewise, administration costs are low, since there are no local harddrives requiring tiresome reinstalls, patching, and backups.

Unfortunately, Thinstation is a little complicated to setup and many organizations insist on having support contracts for their computers. In this case, consider using [PXES Universal Linux Thin Client](#) to set up Windows diskless clients. Like Thinstation, the clients are running a Linux kernel, but can display a Windows terminal from the Windows server. PXES Universal Linux Thin Client is easier to install and configure than Thinstation, and is developed by 2X in case you need tech support.

Even if using Thinstation or PXES Universal Linux Thin Client, remember that you are still required to pay for Microsoft's Terminal Services Client Access Licenses (TS CALs) for each thin client computer. If your goal is to avoid paying software licenses but still be able to use Windows on your thin client network, consider using 2X's [ThinClientServer PXES Edition](#) which doesn't require any licenses for the server or the clients and can run on a server using Windows XP, so it avoids the costly license for Windows Server 2000/2003/2008.

3.9.1. Installing Thinstation 2.2 in a Windows terminal server³⁴

Thinstation is installed in a Windows or GNU/Linux server, but it transfers a basic operating system to diskless clients when they bootup over the network. The Thinstation clients need a minimum of 16MB of RAM, although 32MB of RAM is recommended for running a Windows terminal.³⁵ It is possible to compile your own version of Thinstation, configured

³⁴ Instructions based upon: Paolo Salvan, "CREATING A THIN-CLIENT FOR THE WINDOWS ENVIRONMENT USING "THINSTATION", 14 May 2004, <http://83.89.72.98:8080/>, and readme.txt for the Etherboot PXE Loader (BootPXE535.zip), which can be downloaded from http://sourceforge.net/project/showfiles.php?group_id=80408&package_id=97496&release_id=200769.

³⁵ According to the Thinstation website, is possible to run clients with as little as 8MB of RAM if TinyX is loaded on the server, but there are no clear instructions on the website how to set this up.

to your specifications, if you have a GNU/Linux server, but for Windows users, it is recommended to just download one of the prebuilt images from the Thinstation web site. Go to <http://83.89.72.98:8080/LiveCD/> and download and decompress the file **Thinstation-2.2-prebuilt-NetBoot.zip** (or a later version if available).

3.9.1.1. Installing Thinstation on the server

After decompressing **Thinstation-2.2-prebuilt-NetBoot.zip**, look for the folder **TFtpdRoot** inside. Double click on the file **thinstation.nbi (autoextract).exe** to start installing Thinstation on your server computer.

Read the "License Agreement" for the Citrix ICA Client and click "I Agree" to uncompress the required **thinstation.nbi** file, which is the thin-client boot image. Thinstation.nbi is a mini distribution of GNU/Linux which will be transferred over the network and loaded into the RAM of the client computers when they bootup. Copy all the **TFtpdRoot** folder in your server's C:\ drive (or whatever drive your server boots from).

3.9.1.2. Configuring Thinstation

Inside the **TFtpdRoot** folder you will find the file **thinstation.conf.network**, which is a sample configuration file for the thin-clients. This file is the default configuration for all the thin client computers on your network. You can also create separate configuration files for each client on the network, if they need special settings.

Edit the "**C:\TFtpdRoot\thinstation.conf.network**" file with your favorite bare text editor. You can use Notepad, which is included in Windows, or download the excellent free software program [Notepad++](#).

Everything following the hash symbols # in the file are comments which will be ignored by the computer. Look for the line beginning with "KEYBOARD_MAP=..." and make sure that it matches your keyboard. If using a US-style keyboard, set it to "KEYBOARD_MAP="us"". For a Spanish keyboard, use: "KEYBOARD_MAP="es"". for a Brazilian keyboard, use: "KEYBOARD_MAP="br".

Also check that the screen resolution and refresh rates matches the capabilities of your thin clients' video card and monitor. If using older computers, it is recommended to set the resolution at 800x600, then test higher resolutions later once you have the thin client network working. Look for the line beginning with "SCREEN_RESOLUTION=..." so it reads:

```
SCREEN_RESOLUTION="800x600"
```

Thinstation can display many different types of terminals. To connect to a MS Windows "Terminal Services" session, uncomment the lines by removing the hash marks (#) at the beginning of the lines:

```
SESSION_0_TYPE="rdesktop"  
SESSION_0_RDESKTOP_SERVER="<server name>"      <--- put here your server
```

You will need to set the IP address of your server. So if your server is located at 192.168.0.1, then set the line to read:

```
SESSION_0_RDESKTOP_SERVER="192.169.0.1"    <--- put here your server
```

If you want to connect to a 'Citrix ICA' session, uncomment the lines:

```
SESSION_0_TYPE="ica"
SESSION_0_ICA_SERVER="<server name>"        <--- put here your server
```

Note that you can't have both SESSION_0_ICA_SERVER and SESSION_0_ICA_APPLICATION_SET in the same configuration, so only set one or the other, but not both.

If you want to connect to a 'X' session of a UNIX or GNU/Linux server, uncomment these lines:

```
SESSION_0_TYPE="x"
SESSION_0_X_SERVER="<server name>"          <--- put here your server
SESSION_0_X_OPTIONS=

SCREEN_X_FONT_SERVER="<font server name>:7100" <--- put here your font
server
```

For X sessions to work, your server should be configured to accept "-query" requests, and the font server needs to be able to use port 7100.

3.9.1.3. Choosing different sessions

If you have two or more terminal servers on your network, you can configure Thinstation to provide a menu at bootup, so the user can select which terminal server to connect to. The configuration line "SESSION_0_TITLE=..." will set be the first choice on the menu. If you want your users to be able to connect to sessions from another terminal server, create configuration lines beginning with "SESSION_1_...". For a third terminal server, create lines beginning with "SESSION_2_...", and so on.

For instance, if you have a network connected to a server running MS Windows Server 2003 with Terminal Services at address 192.168.0.1 and connected to another server running Edubuntu GNU/Linux at address 192.168.0.2, then the thinstation.conf.network file would read:

```
# First option on Thinstation bootup menu:
SESSION_0_TITLE="MS Windows terminal"
SESSION_0_TYPE="rdesktop"
SESSION_0_RDESKTOP_SERVER="192.168.0.1"

# Second option on the Thinstation bootup menu:
SESSION_1_TITLE="Edubuntu GNU/Linux terminal"
SESSION_1_TYPE="x"
SESSION_1_X_SERVER="192.168.0.2"
```

```
SESSION_1_X_OPTIONS=
SCREEN_X_FONT_SERVER="192.168.0.2:7100"
```

3.9.1.4. Creating configurations for individual thin clients

Sometimes the default configuration in `thinstation.conf.network` won't work for all your thin clients. The type of keyboard, mice, video card, screen resolution and refresh rate may not be the same for every computer. In this case, configuration files can be created for individual thin clients which will override the settings in the default configuration file. In the same folder where the `thinstation.conf.network` file is located, create files named `thinstation.conf.<IP address>` or `thinstation.conf.<MAC address>`. For instance, if you want to configure two thin clients with the IP addresses 192.168.0.10 and 192.168.0.14, then create the files named “`thinstation.conf.192.168.0.10`” and “`thinstation.conf.192.168.0.14`”. If you are using DHCP to automatically assign IP addresses to your thin clients at bootup, then name the configuration files the MAC addresses of the network cards in the thin clients. To find the MAC addresses for you thin clients, see section [4.6.5. Finding the MAC address](#) .

3.9.1.5. Setting up the TFTP and DHCP server

The TFTP server transfers the `thinstation.*` files to the thin clients during bootup. The DHCP server provides the IP address and the boot-image file name to your thinclient.

Uncompress the `tftpd32` utility you find in 'Tftp\tftpd32o.zip', run it, and in Settings set:

Base directory=C:\TftpdRoot

Exit, go in the "DHCP server" tab and set

IP pool starting address=<IP address>

(put here the first IP address of a free pool of IP addresses of your network, i.e. "192.168.0.90")

Size of pool=<size>

(put here the size of this free pool, i.e. "10")

Boot file=thinstation.nbi

Mask=<netmask>

(put here your subnet mask, i.e. "255.255.255.0")

Press the save button and LEAVE THE APPLICATION STARTED.

After the testing phase, you will probably want to use this utility as a "service", so it will be always running, even when no user is logged on the server; you can download from <http://www.firedaemon.com/> the free "FireDaemon Lite" utility to convert this application to a service.

Otherwise you can read in the last part of this doc how to use the DHCP & TFTP services provided with every Windows 2000 Server.

Note: if a DHCP server already exists in your local network, you should deactivate the `tftpd32` DHCP server (from "Settings") to avoid conflicts and configure the pre-existent DHCP server to supply the information required by

the thin client.

3.9.2. Booting the thin client

Ideally, the thin client can bootup using PXE (Pre-eXecution Environment) which was built into many motherboards after 1999. To see whether your computer has PXE, enter the BIOS during bootup. Generally the BIOS can be entered by pressing F2, ESCAPE or some other similar key. In the BIOS go to the boot device order. Look for an option such as “PXE” or “network” and put it as the first device in the list. (In some BIOSes, you will have to first enable PXE, to may it an option in the list.) Then save and exit.

3.9.2.1. Making an EtherBoot floppy for 30 different types of NICs in MS Windows

If you don't have PXE, you will have to bootup the client computers using EtherBoot, which can be run from a floppy drive, CD-ROM, flashdrive, harddrive, an EPROM chip on a NIC, or loaded into the excess space on a motherboard's BIOS. The easiest of these options is to bootup your client computer from a floppy, although you may want to later think about some of the other options. Thinstation has created a handy floppy which has drivers for the 30 most common types of ISA and PCI NICs. Note that PCMCIA and USB network cards are not supported.

You will need a new floppy disk or a reformatted one which is empty. To reformat a floppy, open Windows Explorer and search for the floppy disk under **My Computer**. Right click on the floppy drive icon and select “**Format**” from the menu.

To create the EtherBoot floppy, go to the folder where you decompressed **Thinstation-2.2-prebuilt-NetBoot.zip**, and enter the **BootDisk** folder. Double-click on the file **BuildFloppy.bat** and it will begin to create the EtherBoot floppy. For more details, see the file **BootDisk\Readme.txt**.

Once the EtherBoot floppy is ready, put it into the floppy drive of the computer that you want boot from the network and reboot the computer. If you see strange errors like "0220 ax:0224 bx:0000 cx:0001 dx:0000", the EtherBoot floppy doesn't have the driver for your particular NIC. In this case it, it is recommended to bootup using Thinstation's boot CD, which contains EtherBoot drivers for many more types of NICs. If you only have a floppy drive available on your thin client computer, you will have to go to the ROM-O-Matic.net website and download the driver for your network card and create a customized EtherBoot floppy. See the section [**EtherBoot**](#) under [**Installing an LTSP thin client network with Edubuntu 6.06 LTS**](#).

3.9.2.2. Creating an EtherBoot CD

Floppies tend to fail over time and are slow, so it is better to bootup your thin client computers from the CD-ROM rather than the floppy drive. To do this, download the file **eb-net.iso** from <http://83.89.72.98:8080/LiveCD/>.

Then use your favorite CD burner to burn the ISO image. If you have Ahead Nero installed, simply double click the file eb-net.iso and Nero will automatically burn the CD image.

If you don't have CD burning software, you can download and install the freeware program [CDBurnerXP Pro](#). From the **File** menu, select the option **Write disc from ISO file**. In the dialog box that opens, click on the [...] button and select the file **eb-net.iso** that you downloaded. Then click on **Write** to begin burning the CD.

Once you have burned the CD, put into the CD-ROM drive of the client computer which you want to boot from the network and reboot it.

4. GNU/Linux thin clients

For a number of economic, moral, and political reasons, many governments and institutions in Latin America are beginning to promote the use of “free software”, which is also known as “open source”, FOSS (Free/Open Source Software) or FLOSS (Free/Libre/Open Source software). Many experts predict that the free operating system GNU/Linux will dominate informatics in the developing world in the future. They advocate switching to GNU/Linux as the way that Latin America can establish technological independence, create local software industries, bridge the digital divide, and dramatically lower the costs of computing.³⁶

GNU/Linux is a free software clone of UNIX, which makes it particularly good for creating thin client networks, since UNIX was designed from the very outset as a operating system for networks. Unlike Windows which was created originally as an operating system for individual microcomputers computers, UNIX and its applications generally work well in network situations. Many Windows programs have problems when used in thin client networks and they require special work-arounds to function properly, especially older Windows software.

Increasingly, network administrators are choosing to run Linux on their thin clients. In 2003, IDC estimated that Linux was used in 20% of thin clients and forecast that it would grow 60% per year—faster than any other operating system on thin clients.³⁷ GNU/Linux is preferred principally because it doesn't have licensing costs, is more secure, and reduces administration costs. Linux clients are largely immune from virus, spyware, and other types of malware. According to a 2001 report by the British government, roughly 60,000 viruses exist for Windows, but only 40 have been created for GNU/Linux and almost all have been confined to the laboratory. With GNU/Linux the network administrator doesn't have to spend so much time wrestling with virus checkers and spyware countermeasures, nor reformatting infected harddrives.

36 For an overview of the benefits of GNU/Linux and why governments should promote its use, see: Amos Batto, “Beneficios de Software Libre para Bolivia”, 27 Apr 2007, <http://www.ciber-runa.net/BeneficiosSoftwareLibreBolivia.pdf>.

37 Sean Michael Kerner, “Linux Gets a Bit Thinner”, *InternetNews.com*, 5 Aug 2004, <http://www.internetnews.com/bus-news/article.php/3391511>.

Many businesses and governments are opting for GNU/Linux because it costs so much less labor to administer and maintain. MS Windows machines require more labor to administer than GNU/Linux because it doesn't permit the automatization of some tasks with scripts. In addition, experience shows that

Windows machines often require periodic reinstalls of the operating system, although the system can be locked down to eliminate this problem. In addition, more time is spent installing security patches and verifying that each machine has the necessary software licenses. A 2005 survey of 955 local governments in Europe found that administrators of free software systems manage 35% more PCs than administrators of proprietary systems. Likewise, a 2006 study of over 200 companies concluded that administrators of GNU/Linux manage more servers and their servers have a higher volume of work than Windows servers. The majority of administrators of GNU/Linux spend 5 minutes per server per week handling patches. 17% reported 0% downtime with GNU/Linux and the majority reported 99.99% uptime. A study by the Robert Francis Group reported that Windows administrators spend twice as much time managing patches

as GNU/Linux administrators. For more information about free software, see [Appendix C: The Free Software Alternative](#).

What are distributions and repositories?

An operating system (OS) can do very little without its accompanying software applications and system tools. Unlike Windows, GNU/Linux bundles both the OS and its applications together, so it is called a **distribution** of software. For instance, Debian 4.0r0 is a distribution since it includes not only the OS, but 14,000+ other programs as well.

In free software, there are new versions of the software quite frequently—sometimes daily or weekly—so it is difficult to keep the applications compatible with the OS. What worked last month might not work today because the kernel or some supporting library has changed. Many free software programs depend upon other programs to run correctly—which are known as **dependencies**. To avoid dependency conflicts, all the software which is known to work together in the same distribution is kept in a storage place on the internet known as a **repository**.

Most GNU/Linux distributions have **official repositories** where they store the software which they have compiled to run with their particular kernel and libraries. People who don't officially work for a GNU/Linux distribution often maintain **unofficial repositories**, which are considered less trustworthy and more likely to have dependency conflicts. Nonetheless, it is often necessary to use unofficial repositories to install proprietary software, codecs, and drivers, which can't be included in the official repositories of the distribution for legal or ideological reasons.

Unlike Windows software which is often downloaded from outside websites, it is recommended that you only download GNU/Linux software from repositories for your distribution. Only if the software isn't available, should you download the software from an outside source. Occasionally it may be necessary to download the source code, and compile the program on your machine to get it to run correctly without dependency conflicts.

4.1. Linux Terminal Server Project (LTSP)

If setting up a network of diskless GNU/Linux thin clients, there are a number of free software alternatives, such as Linux Terminal Server Project (LTSP), Diskless Remote Boot in Linux (DRBL), 2X TerminalServer (PXES), and Thinstation. The best known of these programs is

LTSP, which has been called “the 'granddaddy' of all Linux thin-client open source projects”³⁸. LTSP was founded by James McQuillan in 1998-9 when he was contracted by a medical supply company which needed to run terminals for an AS/400 server and a UNIX server at the same time. Like so many free software projects, McQuillan didn't start from scratch. Instead he wrote a script to control a number of existing programs such as EtherBoot, tFTP (trivial file transfer protocol) and bootp, so that a diskless computer could connect over a network to a server and download the linux kernel, the software to display the X-Windows graphical interface.³⁹ Once these programs are loaded into the RAM of the client computer, programs installed in the server can be run by the client computer.

Unlike many of the other thin client software projects, LTSP is widely used and tested with the major GNU/Linux distributions. It can probably found in the repositories for your favorite Linux distribution. LTSP is rather difficult to install and requires some experience with the command line to setup correctly. Fortunately, several distributions such [K12LTSP](#), [Skolelinux](#), [AbulÉdu](#), [Edubuntu](#), [Xubuntu](#), the [Cutter project](#) and [Deworks](#) have been designed around LTSP so it is much easier to install and setup. These distributions include options to install LTSP from default installation CDs and some also include special tools to better manage the LTSP thin clients. More importantly, they will automatically create the necessary configuration files so that LTSP should run automatically. If using a distribution designed for LTSP, the most difficult task is assigning an Internet Protocol (IP) number to the server and deciding how IP numbers will be assigned to the clients.

GNU/Linux distributions designed around LTSP

Distribution	Based upon	LTSP version	Install CDs	Recommended Minimum Requirements	
				Server RAM	Client RAM
Edubuntu 7.04	Ubuntu 7.04 (which is based upon Debian)	5.0	2 CDs	512MB + 128MB per client ⁴⁰	48MB
Xubuntu 7.04	Ubuntu 7.04 (which is based upon Debian)	5.0	1 CD	256MB + 64MB per client	48MB
K12LTSP 6	Fedora Core 6	4.2	6 CDs	512MB + 64MB per client	32MB
SkoleLinux 2.0r0	Debian 3.1	4.2	1 CD	256MB + 32MB per client	24MB

Setting up LTSP for the first time can a trying experience, especially if you aren't very very familiar with the command line. If you don't have much experience using GNU/Linux, it is strongly suggested that you use one of the GNU/Linux distributions with LTSP already incorporated. Select your LTSP distribution according to the distribution of GNU/Linux which you already use. People who already use Ubuntu, should use Edubuntu (or Xubuntu for less

³⁸ Kerner, “Linux Gets a Bit Thinner”.

³⁹ For a history of the origin of LTSP, see: <http://ltsp.sourceforge.net/longstory.php>.

⁴⁰ The Edubuntu webpage recommends that the LTSP server have 150MB per client, but doesn't specify how much RAM is needed just to run the server without the clients. For this reason, 512MB + 128 is taken as a reasonable guess, since Edubuntu runs well at this configuration in my experience.

powerful thin clients). Users of Debian or one of its derivatives should probably select SkoleLinux (or possibly Edubuntu). People who prefer Red Hat, Fedora, Mandriva, or one of its derivatives should use K12LTSP.

Although most of the LTSP distributions were originally created for schools, even people who want to set up LTSP for businesses, governments or cybercafes may want to first install an LTSP network using these one of these distributions. The educational applications can be removed and the school-related background screen can be replaced. These special LTSP distributions will make it much easier to get the entire network working and figure out how to correctly configure all your thin clients. If you really need a normal GNU/Linux distribution which isn't focused on education, you can later install a normal GNU/Linux distribution and add LTSP, once you have figured out how to get it first working with an LTSP distribution.

Most GNU/Linux distributions use LTSP 4.2 and probably will for many years to come, since it is well tested and highly optimized for low memory clients. In addition, it supports local devices on the thin clients better than in the past. LTSP 4.2 uses a custom-compiled Linux 2.6 kernel and custom system tools. Several years ago James McQuillan started working on a radical redesign of LTSP, so that the thin clients would use the kernel and system tools of their distribution. LTSP 5 is designed around secure authentication and transmission—a feature which competing thin client software offered. When booting up, a SSH tunnel is established between the server and the clients for secure login and communication. McQuillan codenamed LTSP 5 “MueKow” in mockery of Microsoft's “Longhorn”; like Microsoft's “Longhorn”, “MueKow” has been met with mixed reviews. Whereas LTSP 4.2 can be setup on almost any GNU/Linux distribution and runs on clients with as little as 12MB of RAM, LTSP 5 is extremely difficult to implement and requires clients with 3 or 4 times as much RAM. Currently LTSP 5 is only available in Ubuntu (version 5.10 and later) and Debian 4.0, although there are plans to port it to other distributions like Gentoo. It is only recommended to use LTSP 5 in Ubuntu, since it is a nightmare to configure in Debian and essential services like printing and scanning don't work.⁴¹

Some older version of GNU/Linux, still use LTSP 4.1, but it is best to avoid it in most cases. One might assume that LTSP 4.1 would be better for low-memory thin clients, since it uses the older Linux 2.4 kernel, unlike LTSP 4.2 which uses the 2.6 kernel. Generally the 2.4 kernel is considered better for older computers, since it takes less memory and supports older hardware--the new Linux 2.6 kernel no longer supports some of the oldest hardware. Nonetheless, it is not recommended that LTSP 4.1 be used unless you have hardware which requires the Linux 2.4 kernel. The reason is that LTSP 4.1 required at least 20MB in the thin clients, whereas LTSP 4.2 has been slimmed down so it can run on only 12MB RAM (or 8MB if server-side swapping is enabled). In addition, LTSP 4.2 has much better support for local devices.

4.1.1. Edubuntu



Ubuntu is currently the fastest growing GNU/Linux distribution; and many consider it to be the

⁴¹ For instructions on installing LTSP 5 in Debian, see “Installing LTSP in Debian”, <http://wiki.ltsp.org/twiki/bin/view/Ltsp/Debian>.

best of the hundreds of GNU/Linux distributions which are based upon Debian. If you use Ubuntu or some other Debian derivative, it is recommended that you install Edubuntu for your LTSP network. Edubuntu is essentially Ubuntu plus LTSP and some educational applications. Edubuntu is a very nicely packaged distribution with a user-friendly interface, a tasteful design for schools, and useful graphical tools to manage the LTSP network.

Edubuntu and the other Ubuntu flavors (Ubuntu/Kubuntu/Xubuntu) are strongly recommended for people who have no previous experience using GNU/Linux. Unlike many GNU/Linux distributions which are designed for servers, Ubuntu is better designed for desktop users who need a simple interface, rather than more advanced options. New versions of Ubuntu comes out every six months so its versions of software are more up-to-date than most other GNU/Linux distributions. This 6 month release cycle can be a detriment for servers which need their software to be well tested for maximum stability, but it is advantageous for thin client networks which are focused on providing good desktops with the latest software on the clients.



For companies and governments which need tech support, Canonical, the company which makes Ubuntu, can offer support contracts and special configurations. For people who can't pay for special support contracts, Ubuntu has excellent help forums and online documentation. Since Ubuntu is used by a good mix of newcomers and experts, the Ubuntu community has a good reputation for helping novices get started, but also solving the hard technical problems which vex expert users. Finally, many prefer Ubuntu because Canonical seems to be more committed to the ideals of free software than many of the other GNU/Linux companies such as Novell and Red Hat. Canonical's founder, the South African billionaire Mark Shuttleworth, has made a special

commitment to producing Ubuntu in minority languages⁴² and using it in poorer schools. The Shuttleworth Foundation has financed projects to install Edubuntu thin clients in South African schools.

Many are opting for Ubuntu because it comes in only one version for both corporate customers who can pay and normal people who can't afford to pay for their software. In contrast, most other commercial versions of GNU/Linux come in a stabler version which costs (such as Red Hat, SuSE and Linspire) and a more experimental, community version which doesn't cost (such as Fedora Core, OpenSuSE and Freespire). The stabler versions often aren't true free software because they include proprietary codecs, drivers, and other proprietary software. The major downside to Edubuntu and the other Ubuntu flavors is that they only include one windows manager and the most commonly used programs on the installation CD(s). If you want to use other programs or other windows managers, you will have to download them from the Ubuntu repositories on the internet. People who speak any language other than English will also have to download additional language files when installing Edubuntu. People who don't have access to the internet should avoid Edubuntu and opt for a distribution like K12LTSP whose installation CDs include the most of the programs, windows managers, and languages.

4.1.2. Xubuntu

Unfortunately, Edubuntu doesn't run well on clients with less than 96MB of RAM. Edubuntu can boot up on clients with as little as 48MB of RAM, but it takes significantly longer to load and multitask. Once the proprietary multimedia codecs (such as MPEG, MP3, etc), proprietary fonts (TrueType), and other needed extras are added, Edubuntu won't load with only 64 MB RAM. For client machines with 64MB of RAM, it is recommended to use Xubuntu which uses the lighter Xfce windows manager. Xfce in Xubuntu has been reconfigured to mimic the GNOME interface found in Edubuntu, with taskbars on both the top and bottom of the screen. The Xubuntu Alternative Install CD has an option to install LTSP, but unfortunately I have never gotten LTSP to install correctly from the CD (versions 6.10 and 7.04). Hopefully future versions of Xubuntu will correct this problem. Instead, LTSP needs to be reinstalled manually on Xubuntu. See the section [4.7. Installing a thin client network in Ubuntu 7.04](#).

Edubuntu and the other favors of Ubuntu are the only GNU/Linux distributions which have been specially configured to use LTSP 5 ("meukow"). Networks which need the secure authentication and networking which comes in LTSP 5 should choose Ubuntu. In addition, LTSP 5 clients should theoretically be more compatible with the server, since they share the same kernel and configuration. The downside to using LTSP 5 is that it hasn't been optimized for clients with minimal memory like LTSP 4.2, so it won't work for thin clients with less than 48MB of RAM.

If you want to try out Edubuntu or Xubuntu before installing it on your machine, download the Desktop CD version, which is a Live CD designed to be booted up from the CD. It won't install anything on your harddrive, so you can try out the system without any fear of ruining your

⁴² Canonical's Rosetta and Launchpad projects are designed to translate software into other languages. Some free software advocates have criticized these projects because they are based upon proprietary code and the concept that the translations can be privatized and commercialized. Although to be fair, the Shuttleworth Foundation has also financed the Pootle project for translating online with free software.

computer's current configuration. Unfortunately there is no option to try out the LTSP server from the Live CD, so you will need to do a full install on the harddrive to install an LTSP server. To install a server, you will need to download the 2 Edubuntu Alternative Install CDs. For Xubuntu, download the Xubuntu Alternative Install CD. These Alternative Install CDs do not have the graphical installers which are available on the Desktop CDs, but they provide more options.

4.1.3. SkoleLinux



SkoleLinux, which is also known as Debian-edu, is a good option for people who like the power and flexibility of Debian or who believe ideologically in free software. SkoleLinux means “School Linux” and was originally designed by Norwegian developers to run thin clients in their schools. SkoleLinux is an official subproject of Debian, so it uses all of the Debian software, but the SkoleLinux Installation CDs include LTSP, a nicer GNOME desktop for schools, and some educational applications.

Debian is the most commonly-used non-commercial distribution. It is created by a democratic community of over a 1000 volunteers who elect their leaders. Debian developers have a reputation for technical excellence and vociferous advocacy for free software ideals. Many choose Debian because of its renowned stability. It is often used by people who run servers or want to configure their computers for special purposes. Debian can run on [11 different architectures](#) from the standard x86 to tiny ARM processors. More importantly, its repositories are considered some of the most reliable and largest in the world. Often the most obscure free software programs are available in Debian repositories.

The downside to SkoleLinux/Debian is that its administrative tools are not designed for newcomers, and it frequently resorts to the command line tools, rather than graphical tools. It especially lacks some of the graphical tools found in Edubuntu and K12LTSP to administer thin clients. In addition, new versions of SkoleLinux come out every 18-24 months, rather than every six months as with Edubuntu and K12LTSP, so the software is more likely to be out of date.

Currently the stable version of SkoleLinux is based upon Debian 3.1 (Sarge), so it is several years out of date. It is recommended that the “testing” version be used instead. Another options is to switch to Debian 4.0r0 which was just released in April 2007 and has fairly up-to-date software.



SkoleLinux uses LTSP 4.2, so it requires less memory than Edubuntu or even Xubuntu. People have reported running SkoleLinux with as little as 20MB of RAM, although one reported that the clients were unable to use sound and USB flash memory sticks at the same time in the 20MB clients. LTSP thin clients with as little as 12MB RAM can run on a stripped down version of Debian 4.0 with an extremely light windows manager like FluxBox (although they are more stable with 16MB RAM). See the section [4.8. Thin client networks for old computers with Debian 4.0r0](#). Debian also has an option to use LTSP 5, but it is extremely difficult to configure correctly and Debian experts recommend sticking with LTSP 4.2 for now.

4.1.4. K12LTSP

K12LTSP is a GNU/Linux distribution based upon Fedora Core—in fact it even uses the same version numbers as the Fedora Core which it is based upon. Fedora is the community version of Red Hat and is designed to be the test ground for software which eventually will be incorporated into the next version of Red Hat. Although Red Hat calls Fedora “experimental” and regards it as less stable, it is far more reliable than any operating system from Microsoft and is plenty stable for an LTSP server.

Unlike Edubuntu and SkoleLinux which are officially part of Ubuntu and Debian respectively, K12LTSP is an independent project which has been produced by Eric Harrison, Paul Nelson, and other volunteers at the Portland Linux User's Group since 2000.⁴³ K12LTSP sports a well-designed GNOME desktop (although Edubuntu's desktop is simpler for new-comers to use). The main advantage of K12LTSP is its excellent client management tool, which is designed for supervising the thin clients and is an invaluable tool for teachers who want to monitor a classroom.

Like Edubuntu, K12LTSP sports up-to-date desktop applications, since it is based upon Fedora Core which comes out with a new version every 6 months. K12LTSP usually comes out with its version a month or two after Fedora Core is officially released. Since there appears to be no plans to switch to LTSP 5, K12LTSP will probably stick with LTSP 4.2 for the next couple years. This means that K12LTSP is an excellent choice for older thin clients with little memory. Like Debian and Ubuntu, Fedora has an excellent online community who are very willing to answer your questions. For those who are willing to pay, it might be possible to find tech support for K12LTSP, although most tech support companies only officially support Red Hat, not Fedora.

4.1.5. AbulÉdu

AbulÉdu is a French distribution based upon Knoppix / Debian. It may be useful for people who prefer KDE, rather than GNOME, although it isn't as well maintained as SkoleLinux.



4.2. Choosing the Windows Manager for GNU/Linux

Unlike in Windows and Mac which only have one possible graphical user environment, GNU/Linux allows users to select the graphical environment which is best suited for their needs. It does this by separating the graphical display which is X-Windows from the windows manager which controls the menus, taskbars/panels, and management of windows. In fact it is possible to run GNU/Linux without a windows manager, but there will be no menus and the windows can't be moved or resized. Locked-down systems which only run one program often run without a windows manager to prevent users from using the computer for other purposes or tinkering with the system. There are at least [37 different windows managers](#) for X-Windows and the number keeps growing every year.

43 “K12LTSP History”, http://k12ltsp.org/mediawiki/index.php/K12LTSP_History



GNU/Linux Windows Managers

The advantage of all these choices is that the user can select which windows manager to use when logging in. When the thin clients reboot or the user logs out of a session, login managers such as **kdm** and **gdm** will allow users to enter their user name and password, plus select their language and their windows manager. If the thin client is an older machine with little memory, then a lighter windows manager can be selected, but a more powerful windows manager can be selected for new machines with more memory. (If you don't want to give users these options, use instead the **xdm** login manager which only allows the username and password to be entered.)

4.2.1. Heavy windows managers

The best known windows managers are [GNOME](#) (GNU Network Object Modeling Environment) and [KDE](#) (which originally meant the “Kool Desktop Environment”). These windows managers require a great deal of memory and processing power, so they are only suitable for more powerful thin clients. KDE was started in 1996 by a group of Northern European programmers who wanted to replace CDE (Common Desktop Environment) which was commonly used in UNIX at the time. It is extremely configurable, with many options, and visual eye-candy, like bouncing penguins.

KDE is based upon the [Qt](#) library from [TrollTech](#), which was a proprietary library at the time and alarmed many who were committed to the ideals of free software. GNOME was founded in 1997 by two Mexican programmers as a freer alternative, since it is based upon the free [GTK+](#) library. Because GTK+ and GNOME aren't controlled by any one company like TrollTech, the major GNU/Linux companies like Red Hat and Novell could invest heavily in their development without fear. GNOME is considered easier to use since it sports fewer options and has a more staid appearance which appeals to corporate users. Although power-users generally prefer KDE, GNOME is recommended for schools and cyber-cafes where many of the users are beginners.

4.2.2. Light windows managers

The heavy memory and processing requirements of GNOME and KDE make them unsuitable for thin clients with few resources. GNOME can be booted up on a Debian client with a 486 processor and as little as 20MB of RAM, but it won't be able to run once extra goodies such as proprietary fonts and codecs are installed. It is recommended that GNOME thin clients have a 100MHz Pentium I processor and 32MB RAM if using LTSP 4.2 or 48 MB of RAM if using LTSP 5. To run well, GNOME clients really need double these minimum requirements. Fortunately, there are several dozen windows managers designed for older computers which have less RAM and slower processors. These lighter windows managers work well for thin clients which have less than 32 MB of RAM. In addition, they work well for servers which have 64 MB or less of RAM per client.

One of the best of these lighter windows managers is [Xfce](#), because it provides much of the graphical functionality of GNOME and KDE, without taxing the computer's resources too heavily.⁴⁴ Its only drawbacks are the lack of a few graphical configuration tools and its default CD burner, xfburn, is woefully inadequate. This isn't much of a problem since CD burners in LTSP thin clients don't work, although thin clients can be configured to control CD burners installed in the server. If a CD burner is used in the server, install a more powerful program such as K3B or GnomeBaker, or a lighter program such as xcdroast.

4.2.3. Extremely light windows managers

For extremely light clients with minimal memory, there are a number of options. [IceWM](#) runs adequately on LTSP 4.2 thin clients with as little as 16MB RAM (or with 12MB RAM if server-side swapping is activated). It has a normal start menu at the bottom of the screen and several different themes. One of its themes mimics Windows 95, for people who are accustomed to older Windows machines. IceWM has no graphical configuration tools, so you will be forced to manually edit the configuration files. For instance, adding a new application to the start menu will involve opening the menu configuration file, and adding the command to run the application.

For even lighter clients with as little as 12MB of RAM (or 8 MB of RAM with network swapping enabled), try [FluxBox](#), which doesn't even have start menu or taskbar. In FluxBox you can right click anywhere on the desktop to display the menu of applications. It takes a while to get used to FluxBox, and it definitely isn't a good windows manager for places such as an information kiosk or school lab where the users change frequently. You can give FluxBox a test run with Damn Small Linux which makes a 50MB Live CD using FluxBox. Download and burn the Live CD, then reboot your computer and see whether the FluxBox windows manager will work for your needs.

With all the extremely light windows managers, plan on resorting to the command line frequently. If you don't have the time to learn how to use the command line to manually edit configuration files, it is probably a better idea to avoid these windows managers. The upside to using extremely light windows managers is the fact that they are lightning fast and only take a few seconds to bootup. Since there is little overhead to run these windows managers, programs will load and close much faster. In addition, light windows managers discourage people from playing with the system. In business environments when employees attention should be focused on their work, light windows managers which offer few choices are an easy way to stop people from wasting time. When there is no screen saver and no background screen options except for a single color, it simply isn't as fun to fiddle with the settings.⁴⁵

44 According to tests by Lubos Lunak, KDE actually uses less memory than Xfce or GNOME when used with normal software applications. See: <http://ktown.kde.org/~seli/memory/> In my experience with Debian and Ubuntu does not match these test results.

45 Analysts from Gartner coined a term for this needless fiddling and reformatting called “futzing”, which they considered to be part of the TCO (total cost of ownership). Capital Cardiology Associates, a medical firm, tried to calculate the cost of “doodling” which included playing games and fiddling with the settings: \$750 (50hrs) per year on a Windows fat client, \$375 (25hrs) on a GNU/Linux fat client, and \$15 (1hr) on a GNU/Linux thin client. Dr. Martin P. Echt and Jordan Rosen, “Linux thin client conversion in a large cardiology practice: initial

4.3 Getting support for LTSP

Canonical, the company which makes Edubuntu offers support contracts for users of Edubuntu. Their website does not indicate whether this tech support is available in Spanish or Portuguese or includes onsite servicing, but it is certainly available via long distance phone and email in English. In the United States, at least two companies specialize in offering LTSP services. In 1999, James McQuillan, the founder of LTSP, started the company disklessworkstations.com to offer support, customizations, and sell LTSP hardware. disklessworkstations.com sells custom ethernet cards for US\$35, which will boot your PC from the network, so it can become a diskless thin client. Another company from New York, [Symbio Technologies](http://SymbioTechnologies.com), specializes in setting up LTSP thin client networks and converting old PCs into diskless clients. Symbio created the useful program, the [Symbiont Workstation Manager](http://SymbiontWorkstationManager.com) (SWM), which is graphical application designed to setup and configure thin clients.⁴⁶ Both disklessworkstations.com and Symbio are small companies and nothing on their websites mentions providing support in Latin America. The best bet in Latin America is to hire a local expert to setup and/or support the LTSP thin client network. To find such people, post a message on mailing list or bulletin board of local GNU/Linux User Groups (LUGs). See [this list](#) of LUGs worldwide. Optionally, post a message on the [LTSP mailing list](#).

In most cases, people who have technical questions simply go online and ask other LTSP users. Remember to be very specific and provide background information for your questions. Specify your GNU/Linux distribution and its version number and your version of LTSP. If you have a question about an error message, provide a copy of the complete error message. If you are having trouble getting your thin client network to run, provide a copy of your LTSP configuration file (`/etc/dhcpd/ltsp.conf` in LTSP 4.2 or `/etc/ltsp/ltsp.conf` in LTSP 5).

LTSP Support Forums:

- ltsp-discuss mailing list: [SUBSCRIBE](#) [SEARCH ARCHIVES](#)
- IRC Channel - #ltsp at irc.freenode.net
- [Brazilian website for the support of LTSP](#)
- [German web based LTSP support forum](#)
- [Spanish web based LTSP support forum \(new\)](#)
- [Spanish mailing list for discussing and supporting LTSP](#)
- [Greek web based LTSP Support Forum](#)

4.4. Assigning IP addresses

LTSP uses IP addresses to communicate correctly between the server and the thin clients on the local network. The thin clients can be assigned IP addresses automatically by DHCP (Domain Host Controller Protocol) which is running from the LTSP server. Otherwise, you will need to physically assign each thin client an IP number.

experience", Capital Cardiology Associates and Lille Corp., Jun 2004,
<http://www.desktoplinux.com/articles/AT7753498575.html>,
<http://www.desktoplinux.com/files/article004/index.html>.

46 The Symbiont Workstation Manager documentation is available in Spanish, English, and French at:
http://sourceforge.net/project/showfiles.php?group_id=110959&package_id=120255&release_id=244081

The LTSP server must have a fixed IP address to communicate correctly with its thin clients. This can cause problems when the LTSP server is automatically assigned an IP number by a DHCP server on the internet or on the larger network. To avoid this problem, it is recommended that the LTSP server have two Network Interface Cards (NICs). One card will be used to connect to the internet or the larger network, so its IP number can change without problems. The other NIC will have a fixed IP number and will handle communications between the LTSP server and its thin clients. Since all the clients must go through the LTSP server to get access to the internet or the wider network, it is suggested that the LTSP also have a firewall installed.

What is an Internet Protocol (IP) address?

IP addresses (which are also known as “IP numbers”) are the four 8-bit numbers which uniquely identify every domain on the internet. Domains are locations used on the internet. In some cases they are addresses to physical machines connected to the internet, but generally there are multiple domains hosted on a single server. Domains generally have a name, such as ltsp.org or google.com which corresponds to an IP address. For instance, the domain name “ltsp.org” has an IP address 70.91.230.211. Each 8-bit number in the IP address is between 0 and 255, so there are 256^4 or 4,294,967,296 possible IP addresses. When you type in “ltsp.org”, your web browser knows which IP address to use, because it connects to a special server on the internet known as a Domain Name Server (DNS) which returns the IP address for each domain name.

The easiest way to set up the LTSP server is to install a DHCP daemon which will automatically assign the IP numbers to the thin clients every time they reboot. Once the thin client network is functioning without problems, you can go back and assign fixed IP numbers to the clients. Some people like to do this, because it makes it easier to identify thin clients by their IP numbers. Thin clients can also be identified by their MAC numbers, which are the six 8-bit hexadecimal numbers such as 00-C0-9F-F6-CC-B3 which are assigned to every NIC. Normal names like “Einstein” or “workstation1” can also be assigned to the thin clients based upon their IP numbers or MAC numbers.

4.5. Alternative ways to setup thin client networks in GNU/Linux

Diskless Remote Boot in Linux (DRBL)

A less known alternative to LTSP is Diskless Remote Boot in Linux (DRBL) from the NCHC Free Software Labs in Taiwan. DRBL is free software and can be installed on almost any distribution of GNU/Linux, including Debian, Ubuntu, Mandriva, Red Hat, Fedora, CentOS and SuSE. Many consider DRBL to be better than LTSP because it allows for distributed hardware resources between the server and the clients. In other words, DRBL can share the RAM between the server and the clients and utilize the client's harddrive for server swap space. Moreover, DRBL is able to fully detect the local hardware of the clients, so it doesn't require complicated fiddling to use local drives like LTSP.⁴⁷ DRBL also includes [Clonezilla](#), a partitioning and disk cloning utility similar to Symantec Ghost. Therefore DRBL is an excellent option for thin client networks which need to be returned to their previous state. For instance, an administrator of a cyber-cafe or school lab who wants revert all the computers in the network to their original format each morning might

47 Frank Tuzi, “DRBL: A quick and easy thin client server”, 2 Oct 2006, <http://tips.linux.com/article.pl?sid=06/09/20/1837209&from=rss>.

want to use DRBL with Clonezilla. Unfortunately, DRBL is less supported and doesn't have any GNU/Linux distributions like Edubuntu, Skolelinux and K12LTSP which are specifically designed around it. Nor does it have a companies like Canonical, Symbio Technology and DisklessWorkstation.com supporting its development or offering tech support.

2X TerminalServer

2X TerminalServer is an attractive alternative to LTSP and DRBL for people who want more polished software with a nice graphical administration tools and a user-friendly setup. Like LTSP and DRBL, 2X TerminalServer is free software for creating GNU/Linux networks with X-Windows thin clients, but it offers graphical management tools to administer the terminal server remotely from any web browser. By default 2X TerminalServer uses the NX protocol, which compresses and encrypts standard X-Windows video so it can reduce the network load and create Wide Area Networks (WANs) which function over phone lines and low-bandwidth connections. NX compression can also be enabled in DRBS and LTSP, but it isn't included by default and is more difficult to implement. Like LTSP 5.0, 2X TerminalServer tunnels all communication to the clients through SSH for greater security. 2X TerminalServer can be used in mixed environment networks as well, since it can translate and tunnel Microsoft's RDP, Citrix's ICA, and the VNC protocols to the clients.

TerminalServer is developed by [2X](http://2X.com), an innovative company which originally started as the [PXES](http://PXES.com) free software project to create diskless thin clients. It proved to be such a popular program, that its founder decided to start the company 2X to commercialize thin client software. 2X has since created a number of proprietary products to compete with Citrix, Microsoft and ThinSoft. 2X encourages people who don't need tech support to use TerminalServer for gratis, but also offers tech support contracts for customers who need more handholding and user assistance.

2X TerminalServer can be used in disked thin clients, but it also works in diskless thin clients, since it has incorporated the old free software project PXES into TerminalServer. Like Thinstation, PXES was based upon the old Netstation project and boots up diskless clients by transferring a basic operating system over the network to the client. 2X TerminalServices (with PXES incorporated) is better packaged and the graphical startup screen is nicer than the scrolling bare text on the startup of Thinstation and LTSP. It is probably better in corporate environments where appearance is crucial, but it requires that the client machines have at least 32MB RAM. For this reason, it is not recommended that 2X TerminalServer be used with extremely old hardware like LTSP.

Thinstation

Thinstation is a free software project based upon the now-defunct netstation project, which creates diskless clients in almost any type of thin client network. Like LTSP and DRBL, Thinstation transfers a basic GNU/Linux operating system over the network and loads it into the RAM of the clients. LTSP and DRBL, however, include a terminal server, whereas Thinstation simply displays terminals from almost any type of terminal server. It can handle Microsoft's RDP, Citrix's ICA, X (X-Windows protocol), NX (compressed X-Windows protocol), 2X ThinClient, Cendio ThinLinc, Tarantella, VNC, telnet, tn5250, VMS term, and SSH protocols. Thinstation's flexibility allows diskless thin clients to be setup in almost any kind of network. Many network

administrators turn to Thinstation when they want to setup Windows terminals, but they don't want to pay for expensive operating system licenses on the client machines. Using diskless thin clients saves on hardware costs, since there are no harddrives, CD-ROMs, or floppy drives to buy. Since there are no moving parts, there are few hardware failures (which become increasingly common with older machinery). Most importantly, there are no operating systems on the harddrives of the client computers to worry about, freeing up the network administrator for more important tasks.

VNC

Sometimes it is necessary to access another computer on the network. There are a number of options for creating this type of hybrid client which can use the local operating system, but can also access the resources of another computer. Many network administrators who want to remotely control another computer install a graphical desktop sharing program such as VNC (Virtual Network Computing) or [tightVNC](#). This program transmits the keyboard and mouse events from a remote computer to a host computer, then relays screen updates back over the network. VNC runs on almost all platforms including Windows, UNIX and Mac, and is very useful when trying to connect to another type of computer. For instance, many network administrators on Windows machines, use VNC to remotely control a GNU/Linux server.

VNC for Windows is designed for one computer to remotely access another computer, rather than creating a whole network of thin clients. VNC on UNIX or GNU/Linux, however, can initiate multiple desktop sessions, so that it can be used to create a thin client network. VNC can't bootup diskless thin clients (although it might be possible to run VNC inside a diskless client).

rdesktop

rdesktop, which stands for “remote desktop”, displays Microsoft's RDP protocol on a UNIX or GNU/Linux machine. rdesktop allows GNU/Linux clients to use the Terminal Services from a machine running Windows Server NT 4.0/2000/2003. rdesktop is extremely useful in mixed networks where GNU/Linux and Windows clients have to share a network. Some network administrators who want to save on licensing costs also use rdesktop on GNU/Linux clients, so that they can use buy expensive Microsoft Windows operating system licenses for each client. As an added benefit, they don't have to worry as much about managing the clients, since GNU/Linux machines rarely acquire virus, spyware, and malware. They rarely become misconfigured and users can't install unwanted software as easily as on a Windows client. Typically rdesktop is used in clients which have a local operating system installed on their harddrive, but rdesktop it can also be used with diskless clients. Thinstation and 2X have incorporated rdesktop into their software, and rdesktop can be run on a thin client network with LTSP or DRBL.

4.6. Installing a LTSP thin client network with Edubuntu 6.06 LTS

This is a quick dirty guide to installing Edubuntu 6.06 LTS which is designed for beginners. It will not cover all the possible installation options, nor will it cover many of the advanced topics. These instructions will only setup a basic LTSP thin client network. You should be prepared to

read the documentation online and/or ask questions in the Ubuntu forums if you run into problems or want to configure your network in a special way.

If you have the latest version of Edubuntu which is currently 7.04, it is essentially the same installation process as 6.06 LTS, but a couple of the installation steps have been reduced by providing default values. See the Edubuntu 7.04 release notes [here](#). If you plan on installing multiple operating systems on the same computer, see [Appendix D: Multibooting](#).

4.6.1. Downloading Edubuntu

The Edubuntu installation CD is available for download from <http://releases.ubuntu.com/edubuntu>. Chose the ISO CD image which is designed for the the architecture of your LTSP server. If you have Intel (x86) based machine such as a Pentium 4, Pentium D, Pentium Core 2 Duo, or a Xeon or old 32 bit AMD processor, chose the file that ends in **i386.iso**. If you have a 64 bit AMD processor such as an Athlon64, Athlon64 2X or Opteron, chose the file that ends in **amd64.iso**. PowerPC processors which are used in IBM Power and Macs (before Apple decided to switch to Intel processors), should use **ppc.iso**. If unsure which processor your server uses, download the file ending in **i386.iso**. Once you have downloaded the ISO image with your favorite download manager (such as GetRight or wget), burn the ISO image to a CD. See [Appendix A: Downloading and installing software and burning CD/DVD images](#).

Insert the CD into the machine which you want to be your LTSP server and reboot the computer to proceed with the installation.

4.6.2. Installation

When the CD starts up, you will be greeted by a startup screen with various options:



At the startup screen it is recommended to first select the option **Check CD for defects** and scan the installation CD for any defects that might have been caused during downloading or burning the CD. Although it takes an extra 7-15 minutes to check a CD for defects, it is worth the trouble because you don't want to discover an error in your CD half-way through an installation.

If the CD is scanned without problems, the computer will reboot and return to the startup screen.

At the startup screen you can also set advanced options such as the display setting for your monitor by pressing the appropriate function keys listed at the bottom of the screen. Normally you won't need to select any of these advanced options, but if your installation runs into problems, you may need to return to this screen and select the options for your computer.

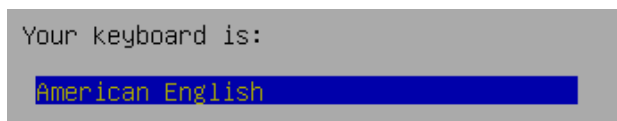
To begin the installation of a thin client server, select **Install to hard disk**. This is the default option, so it will be selected automatically if you press **Enter**.

The Edubuntu installer will start, some text messages should flash across the screen for a couple seconds. When the language selection screen appears, use the arrow keys and press **Enter** to select the language which you want to use, such as **Spanish - español** or **Portuguese (Brazilian) - Português (Brasileiro)**. This language will also be your default language for your system when it finishes installing.

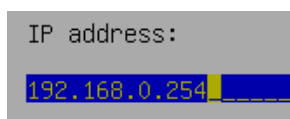
Next, choose your location. This option will determine your time zone as well.



Then, choose your keyboard layout. In Latin America, most keyboards are Latin American, United States—international or Spain.



The Edubuntu installer will try to detect your networking hardware, and then prompt you for an IP (Internet Protocol) address, which identifies your computer on the network. If you're installing a terminal server, and are unsure what to enter here, use "192.168.0.254".



Next, enter the netmask, which will generally be "255.255.255.0".

```
Netmask :  
255.255.255.0
```

Next, choose the default gateway. If you don't currently have one, use "192.168.0.1".

```
Gateway:  
192.168.0.254
```

Next, enter your domain name server (DNS) address. If your thin client network will have access to the internet, enter the IP address to a domain name server on the internet, such as "200.192.128.40". If your thin client network won't have internet access, you can use the IP address of your server.

```
Name server addresses:  
192.168.0.254
```

Next, enter your proxy server address. Most of the time this field will be left blank, unless the computers on your network have to go through a proxy server to get access to the internet. If you don't have a proxy server, leave this field blank by simply pressing **Enter**.

```
HTTP proxy information (blank for none):  
 
```

The next step is partitioning your harddrive. If you don't plan to run any other operating system on the computer and don't have any data that you want to save, then choose the option "Erase Entire Disk".

```
Partitioning method:  
Erase entire disk: SCSI1 (0,0,0) (sda)  
Erase entire disk and use LVM: SCSI1 (  
Manually edit partition table
```

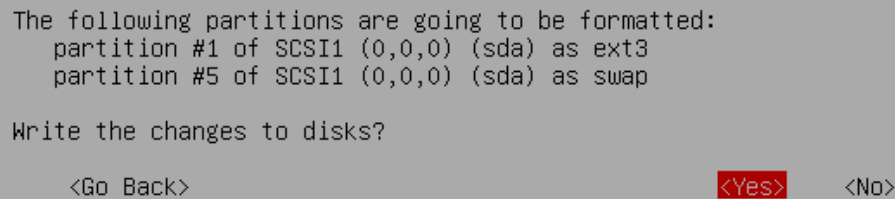
If you want to keep your existing data and/or operating systems on your harddrive, the partitioner has an option to automatically resize the existing partitions to make space for a new partition

where Edubuntu will be installed. You will be given the option to decide how large this new partition will be. If you don't know, it is best to accept the default sizes selected by the partitioner.

Another option is to manually partition your harddrive. Remember that you will need one partition for Edubuntu and one swap partition. Edubuntu will need at least 2.5GB of disk space, but you will probably want to provide much more. The swap partition is the overflow space used when there isn't enough room in your RAM. Often when switching from one program to another, the memory from the old program is stored in the swap partition. The swap partition should be at least as large as your RAM, so if you have 1024MB of RAM, make your swap a tad larger to hold all the memory in the RAM.

Unfortunately, manual partitioning does not provide an option to resize existing partitions. If you want to resize an existing partition and still use manual partitioning, you will need to exit the installer by rebooting. The easiest way to resize an existing partition is to use one of the Ubuntu Live CDs which has the **gparted** disk partitioner. If you don't have one, download the Edubuntu Desktop CD. When the Live CD boots up, open "**Disk Partitioner**" which is found in the **System** menu. From there you can resize an existing partition. Then exit and reboot using the Edubuntu Alternate Install CD and start the installation all over again.

Next, confirm that the partitioning by choosing "Yes":

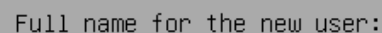


```
The following partitions are going to be formatted:
partition #1 of SCSI1 (0,0,0) (sda) as ext3
partition #5 of SCSI1 (0,0,0) (sda) as swap

Write the changes to disks?

<Go Back> <Yes> <No>
```

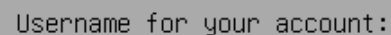
You will then be prompted to enter information for the first user that will be added to the system. This user will have administrator rights to the system. Since you are setting up a thin client network, you will probably want a generic name, such as "Network Administrator".



```
Full name for the new user:
```

Lab Administrator

Next, enter a username for this user. The username must be a single word containing only lowercase letters and no spaces, such as "admin" or "sysadmin".

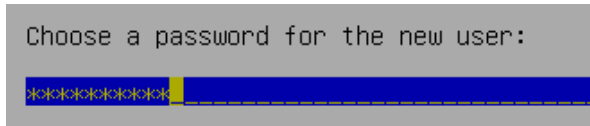


```
Username for your account:
```

sysadmin

Enter a password for the user. Avoid using weak passwords such as "admin" or any other words you might find in a dictionary. Also avoid simple passwords or patterns on your keyboard. A strong password contains a mix of upper-case, lower-case, numbers, and symbols, such as

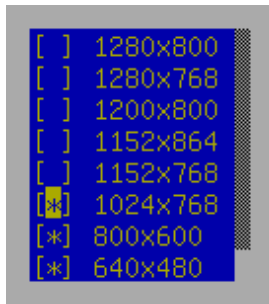
"l8eM5piiMr2" or "pt0-3f!steE". Remember that all the users of your thin client network will probably be storing their files on the server. The only account which will have access to all that data will be this user who has administrator rights. People might have reasons to want to crack this account and get access to that data, so it is a good idea to set a strong password.



You will need to confirm the password by typing it again in the password confirmation dialog. Now, the Edubuntu installer will start installing the base system, which can take a long time depending on the speed of your system.

If you are curious about what is being installed on your system, each package is listed while it is extracted (decompressed) and installed. The installer will not only install the operating system for the server, but it will also build another operating system which thin clients will use to boot. This is often referred to as the "thin client environment" or the "LTSP chroot".

Once the base system is installed, you will be asked to provide information about your graphics system. Select the resolutions that your graphics card and monitor is capable of displaying. If you're unsure, simply press ENTER, the installer should detect the correct capabilities of your hardware.



The installer will then complete the Edubuntu installation, and you will be prompted to reboot. Remove the Edubuntu CD and press **Enter (Entregar)** to reboot. You should now be able to bootup in Edubuntu.

4.6.3. Configuring the Diskless Thin Clients

The minimum requirements for an Edubuntu thin client computer is a Pentium II with 48MB RAM and a 2BM graphics card. Recommended specifications are at least a Pentium II 300Mhz with 64MB RAM and a 4MB graphics card. If proprietary goodies are added such as fonts (TrueType), codecs (MPEG, MP3, WMA, etc.), Adobe Flash and Shockwave, SUN Java, and 3D graphics drivers from nVidia or ATI, the thin clients will need a minimum of 96MB or 128MB of RAM.

4.6.3.1. PXE (Pre-eXecution Environment)

The thin client computers will also need to be able to boot over the network. Most newer motherboards (and network cards) built after 1999 have built-in PXE software that allows a computer to boot from the network. The BIOS of the thin client computer will have to be configured to allow the computer to be booted from the network. Reboot the client and press F2, Escape, or whatever key allow you to enter the BIOS. (If you don't know, a message will usually flash by during boot telling you which key to press). Once in the BIOS, check to see whether there is an option to enable "PXE" or "Network Boot". If this option exists, enable it. Then look for the device boot order of your computer. Generally you find that CD-ROM or hardrive are the first devices listed for your computer. Put "Ethernet" or "Network" as the first device on the list. If you don't see any of these options, then you probably don't have PXE on your computer, so you will have to use EtherBoot to network boot. If your motherboard has a built-in NIC, the BIOS option will often only work for the built-in NIC, but won't work for a NIC on an add-in card.

4.6.3.2. EtherBoot

EtherBoot is a program loaded onto a floppy, harddrive, optical drive, the EPROM in a NIC (Network Interface Card) or inside the motherboard's BIOS which allows a computer to boot off the network. Etherboot is not compatible with all NICs. EtherBoot can work with older ISA NICs and 10Mb/s PCI NICs, but it is recommended that you go and find a newer 10/100 Mb/s PCI NIC if your motherboard will support it. 10/100 PCI NICs can be bought new for as little as US\$5 each and often they can be found used for as little as US\$2. Many people recommend using the same type of NIC in all the machines, since it greatly simplifies network management. Once they find one compatible NIC, they buy the same NIC for all their machines.

The first step is to find out whether your NIC is compatible with EtherBoot. If you are using a PCI NIC, you will need to know its PCI number. Below are instructions for doing this in GNU/Linux and Windows.

In GNU/Linux

If the thin client is running GNU/Linux, open a terminal window, and enter as root (or the user with administrator rights if using Ubuntu/Edubuntu). If you don't have GNU/Linux installed, then use a Live CD to boot up into Linux. (If you don't have a Live CD, then download a Edubuntu Desktop CD).

Then use **lspci** to find the PCI number.

```
su      (or sudo -i if using Ubuntu/Edubuntu)
        enter root password (or first user password if Ubuntu/Edubuntu)
lspci -l
```

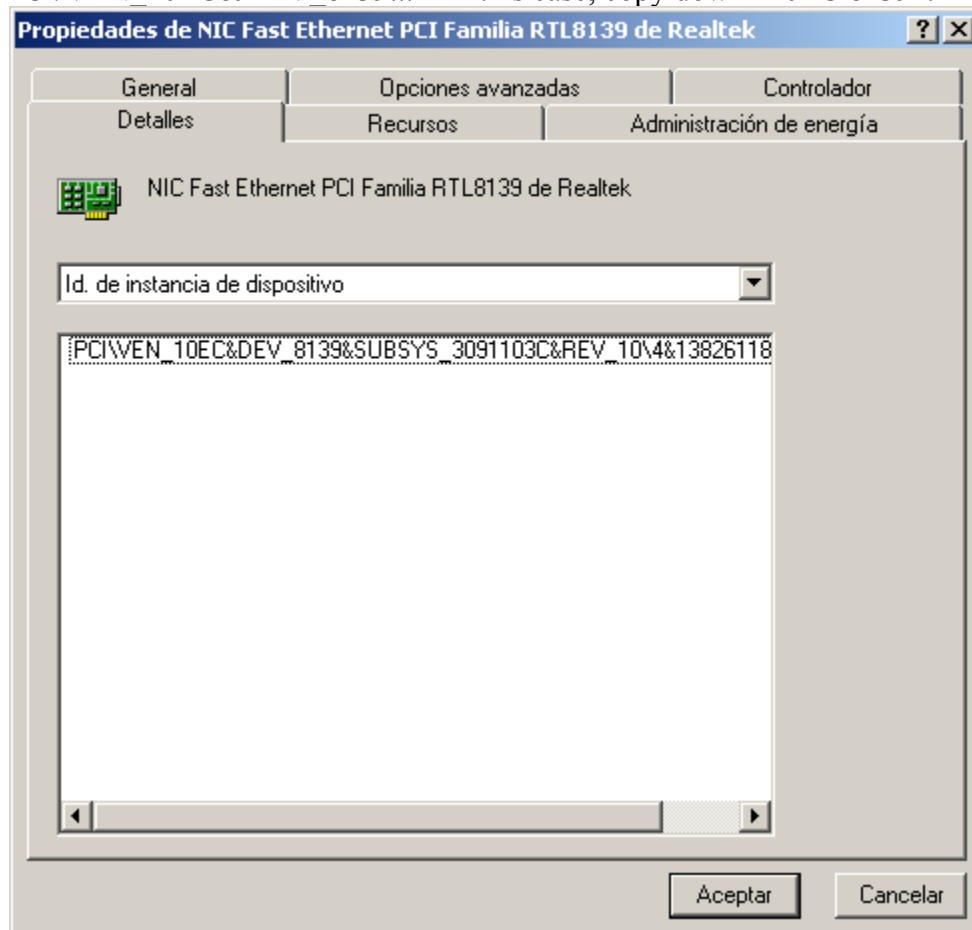
Once you have found the NIC in the list of PCI devices, then find and copy down its PCI number:

```
lspci -n
```

In MS Windows

If using Microsoft Windows, the NIC might be identified by the Windows Device Manager. Right click on the "My Computer" icon and select "Manage", then click "Device Manager". It can also

be opened with the command “devmgmt.msc” in DOS or from **Start > Run**. Once inside the Windows Device Manager, select “Network Adapters”, and double click on your NIC to open the Properties window. Select the “Details” tab. In the drop-down box, look for the property “Device Instance ID”. The ID will list the PCI Vender number, then the Device number. It will appear in a form like “PCI\VEN 10EC&DEV 8139...” In this case, copy down “10EC 8139”.

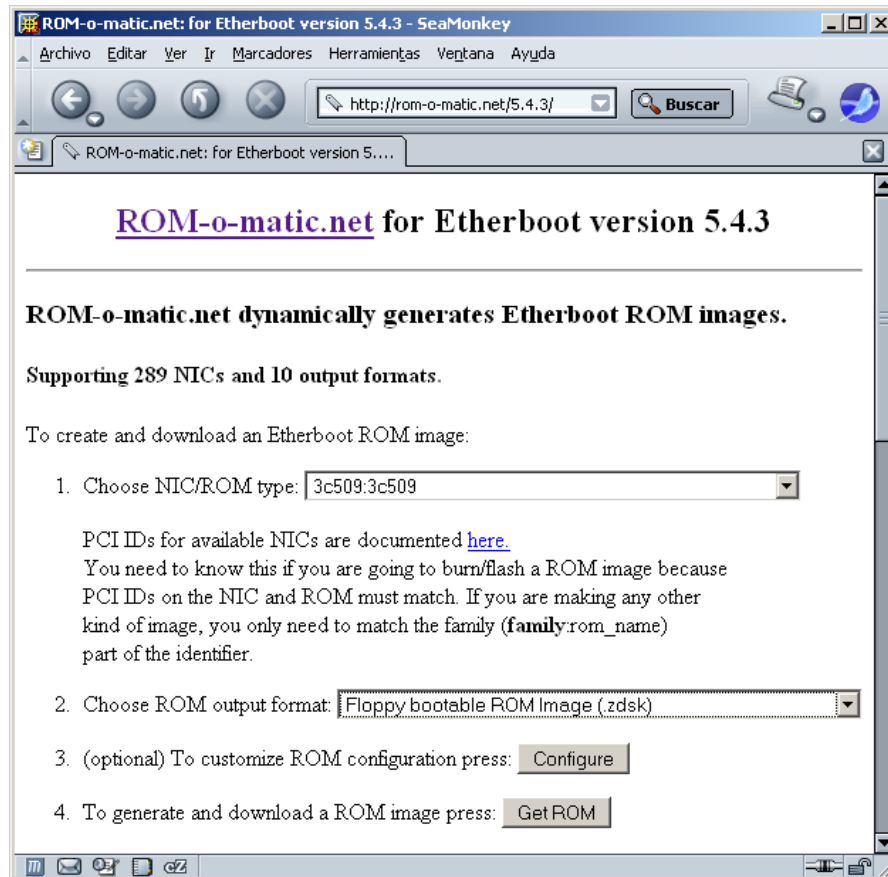


If you can't find the PCI number, several 'detective' programs that may be of aid in identifying your NIC can be found at <http://www.pigtail.net/LRP/swap.html#nic>

Check the [list of NICs](#) and [chips](#) on the EtherBoot web site to see whether your NIC will work and which EtherBoot driver you need. Make sure to read the comments, because sometimes a jumper has to be enabled, a different port set, etc.

4.6.3.3. Making an EtherBoot boot floppy disk

To create a network boot floppy, go to the website ROM-O-Matic (<http://rom-o-matic.net>), which has made EtherBoot drivers for different NICs. Chose the latest production release of the software. (At the time of this writing, it is version 5.4.3). If you have an older NIC (especially an ISA card), you may have to search through some of the older versions of EtherBoot to find the driver for your card.



After selecting the EtherBoot version, you will be presented with a web form to select the EtherBoot driver for your NIC. First, select your NIC (Network Interface Card) type from a pull-down menu. You may be able to find your NIC according to its chipset, or you may need to search for its PCI number.

Then, select which format EtherBoot will be installed on. If you are creating a boot floppy, select "Floppy bootable ROM image (.zdisk)". The formats with **z**, such as **.zdisk** are compressed, whereas **.disk** is uncompressed. The compressed format should work in almost all cases.

You can configure EtherBoot to use a number of options. One which might be useful is the number of seconds to wait at bootup before starting the EtherBoot program. By default, this is 10 seconds, but you might want to set it to 0 if the computers will always boot up as thin clients. If you want users of your thin client network to have a choice whether to boot up as thin clients or not, you might set this to a longer time period.

Click on the "Get ROM" button to begin downloading an EtherBoot floppy image.

Once you have downloaded the EtherBoot floppy image, you can write the image to a floppy in either a Windows computer or GNU/Linux computer.

In a GNU/Linux computer:

Insert a blank floppy disk in the drive and open a terminal window. Switch to the directory where you downloaded the floppy boot image and issue the command:

```
cat etherbootfile.zdisk > /dev/fd0
```

Replace “etherbootfile.zdisk” with the name of the floppy boot image which you downloaded from the ROM-O-Matic website.

In a Windows computer:

You will need to obtain the program [Rawrite2](#), which can be downloaded [here](#) or can be found on Thinstation's “Universal Network Boot Floppy” (see below). Once you have obtained Rawrite2, open DOS. (In Windows XP, DOS can be opened at **Start->All Programs->Accessories->System Symbol**). Inside the DOS window, switch to the directory where you have downloaded your EtherBoot floppy image and issue the command:

```
rawrite2 -d A -f etherbootfile.zdisk
```

Replace “etherbootfile.zdisk” with the EtherBoot floppy image which you downloaded from the ROM-O-Matic website.

You will need to make EtherBoot floppies for all the computers which will be thin clients on your network. If you have an ISA NIC rather than the standard PCI NIC, you will follow the same procedure for creating an EtherBoot floppy, but you will also need to modify the dhcp.conf file to correct use the ISA NIC. See the section [4.8.7. Using ISA network cards](#).

EtherBoot runs more slowly off a floppy or CD, but it is the easiest to test on those formats. Once you have verified that it works off a floppy or CD, you may want to install EtherBoot on your harddrive or burn an EPROM on a NIC.

4.6.3.4. Alternatives to using ROM-O-Matic

If you have many different types of NICs in your thin client network, downloading and creating a dozens of different boot floppies can be a real hassle. [Thinstation](#) has created a handy “Universal Network Boot Floppy” with EtherBoot drivers for the 30 most common types of NICs. In addition, thin station has created Universal Network Boot programs to install on harddrives and CDs. To use Thinstation's floppy, download [BootDisk522b.zip](#) from Thinstation's [downloads page](#). In GNU/Linux, issue these commands to create the floppy:

```
unzip BootDisk522b.zip
cp ebnet522.dsk /dev/fd0
```

If your thin clients have a CD-ROM drive, 2X has created the ThinClientOS v.4.1 CD to boot with EtherBoot drivers for every type of supported NIC. This is a very useful tool when you don't know which EtherBoot driver to use. The CD image can be downloaded [here](#).

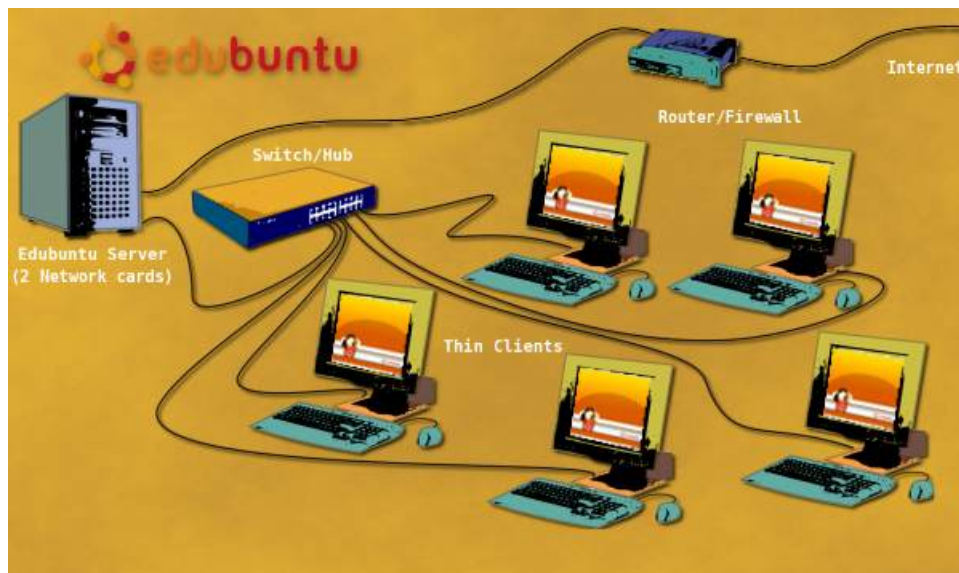
Set the client to boot from floppy

Enter the BIOS of each client computer by rebooting and pressing F2, ESCAPE, or some similar key. (There should be a message at startup which tells you which key to press to enter the BIOS.) Look for the boot order and set the floppy drive as the first boot device. Save your settings and exit the BIOS.

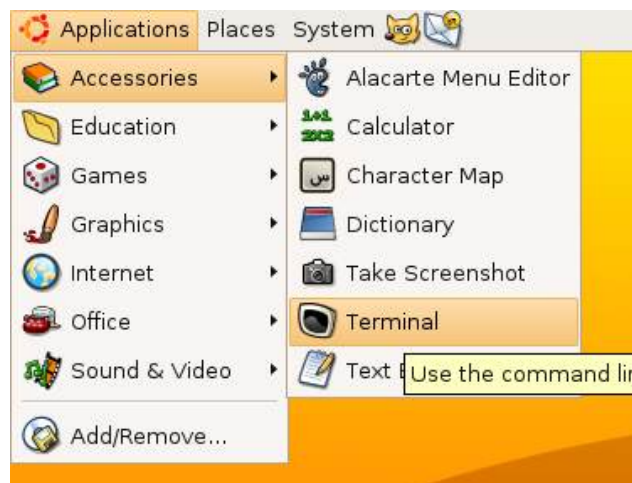
4.6.4. Connect the computers

Connect all the computers in a star topology, which means that each workstation and the server

are connected directly to the networking switch. For security purposes a firewall can be connected directly to the server or to the switch. If you will be connecting to the internet, it is recommended that the network also have a firewall which can be connected to the switch or directly to the server. It is recommended that the firewall be connected directly to the server, since it saves an extra port on your switch and is easier to configure:



Once all your computers are connected, you may need to adjust the settings on your server. If you set your server's IP address as "192.168.0.254" or any IP address ranging from 192.168.0.1 to 192.168.0.254, then you probably won't need to change anything. If you chose an IP address in another range, such as 10.0.0.254, then you will need to edit the DHCP daemon's configuration file on the server. Open a terminal windows by going to the **Applications** menu, pointing to **Accessories**, and clicking on **Terminal**.



Now log in as your administrator user (this is the first user account which you created when

installing edubuntu):

```
sudo -i
```

Enter the password to the administrator user

```
nano /etc/ltsp/dhcpd.conf
```

(If you want to use a graphical editor you can use: gedit /etc/ltsp/dhcpd.conf)

The dhcpd.conf file will look something like the following:

```
authoritative;

subnet 192.168.0.0 netmask 255.255.255.0 {
    range 192.168.0.20 192.168.0.250;
    option domain-name "example.com";
    option domain-name-servers 192.168.0.1;
    option broadcast-address 192.168.0.255;
    option routers 192.168.0.1;

    option subnet-mask 255.255.255.0;

    filename "/ltsp/pxelinux.0";
    option root-path "/opt/ltsp/i386";
}
```

You will need to change all the IP addresses to the same network as your server. So if your server has an IP address of 10.0.0.254, then all the occurrences of "192.168.0" need to be changed to "10.0.0". In this example, your dhcpd.conf file will now look like:

```
authoritative;

subnet 10.0.0.0 netmask 255.255.255.0 {
    range 10.0.0.20 10.0.0.250;
    option domain-name "example.com";
    option domain-name-servers 10.0.0.1;
    option broadcast-address 10.0.0.255;
    option routers 10.0.0.1;

    option subnet-mask 255.255.255.0;

    filename "/ltsp/pxelinux.0";
    option root-path "/opt/ltsp/i386";
}
```

If your clients will be connecting to the internet, you may want to set the Domain Name Server to the address of a Domain Name Server on the internet, such as:

```
option domain-name-servers 200.192.128.40;
```

Remember to watch the semi-colons at the end of the lines and don't accidentally erase them. When done editing the file, close and save it.

If you altered the dhcpd.conf file, you will need to restart the DHCP server:

```
/etc/init.d/dhcp3-server restart
```

When DHCP server is restarting, the last message must display an [ok] tag at the end of the line. The first tag may say [fail] if the server is not started yet. This is normal.

A screenshot of a terminal window titled 'admin@edubuntu: ~'. The window shows the output of the 'dhcp3-server restart' command. It displays the ISC DHCP Server V3.0.3 copyright notice, followed by the message '* Stopping DHCP server' with a '[ok]' status tag. Then it shows the same copyright notice again, followed by '* Starting DHCP server:' with another '[ok]' status tag. The prompt 'admin@edubuntu:~\$' is visible at the bottom.

```
admin@edubuntu: ~
File Edit View Terminal Tabs Help
Internet Systems Consortium DHCP Server V3.0.3
Copyright 2004-2005 Internet Systems Consortium.
All rights reserved.
For info, please visit http://www.isc.org/sw/dhcp/
* Stopping DHCP server [ ok ]
Internet Systems Consortium DHCP Server V3.0.3
Copyright 2004-2005 Internet Systems Consortium.
All rights reserved.
For info, please visit http://www.isc.org/sw/dhcp/
* Starting DHCP server: [ ok ]
admin@edubuntu:~$
```

Your thin clients should now be able to boot up from the server. If it doesn't work, try rebooting the server. Once the server is running, try rebooting a client. When the client booting, you should see a message indicating that it is searching for an IP address from the DHCP server. If it is unable to obtain an IP address, then your DHCP server is either not running, or you might have another DHCP server on the network which is creating a conflict. If you suspect the latter case, disconnect your thin client network from the internet or the wider network. If the clients are able to boot up without any problems, then you probably have a second DHCP server on your network. To get around this problem, the easiest solution is to buy a second NIC for your server and connect it to the internet or the wider network. The thin client computers will be running off their own private local network, so they won't interfere with the other DHCP server.

Another possible solution is to limit the range of both DHCP servers so they don't overlap. In the LTSP server, you can limit the range by changing the **range** option in the `dhcpd.conf` file. For instance if you only want to assign IP numbers between 60 and 80 to your clients, you could set the range option:

```
range 10.0.0.60 10.0.0.80;
```

If you run into any problems, post a message at www.ubuntu-forums.com or subscribe to the edubuntu-users mailing list at <http://lists.ubuntu.com>.

4.6.4.1. Fine-tuning the thin client setup

You might want to alter the setup of some of the workstations. For example, you might want to disable or enable sound, or you'd like to change the display resolution, or even the keyboard layout. The Edubuntu server has the option of a configuration file to fine-tune your thin client settings. This file is available at `/opt/ltsp/(ARCH)/etc/lts.conf`. Replace (ARCH) with your architecture, for example, if you installed the i386 version, you'll need to create a file under the

name `/opt/ltsp/i386/etc/lts.conf`, as it is not installed by default, and then open it for editing.

Below is an example of an **lts.conf** file:

```
# The Default section covers settings that apply to all thin clients

[Default]

# XSERVER: Thin client display driver. Drivers examples:
# ati cirrus cyrix fbdev i128 i740 i810 mga neomagic nv
# r128 radeon rendition s3 s3virge savage siliconmotion
# sis tdfx tga trident tseng vesa vga.
XSERVER = auto

# Keyboard type. In Latin America, keyboard type is likely to
# be "es(pc104)" or "es(pc105)"
XkbSymboles = "us(pc101)"

# US-style keyboards only have 101 keys (or 102 keys for the
# Windows key). Most keyboards in Latin America, have 104
# keys for the extra spanish letters (or 105 for Windows Key)
XkbModel = "pc101"

#Keyboard layout. If have spanish keys: "es"
XkbLayout = "us"

RCFILE_02 = floppyd

# SOUND: Enable / Disable Sound. Options: True False
SOUND = True

# NETWORK_COMPRESSION: Enable / Disable Network compression.
# Options: True False
NETWORK_COMPRESSION = True

# ----> End of DEFAULT section ---->

#[MAC ADDRESS]: unique number identifying each thin client
[00:11:25:84:CE:BA]
XSERVER = vesa
```

This example file covers a lot of `lts.conf` settings. The `#` signs at the beginning of the line indicates a comment, it makes no difference if these lines are removed, all lines starting with a `"#"` are ignored by the system. There's two sections in this example `lts.conf` file. The Default section, and the section that contains an address of one of the workstations (00:11:25:84:CE:BA). Settings that apply to all workstations belong in the default section, while exceptions belong in per thin client setting sections. Within each section, you can use various tags to explain what you'd like to change. For example, if I'd like to specify that all my thin clients use NVidia display cards, I can use a tag called "XSERVER" to specify this. "XSERVER = nv" would specify that I have NVidia display cards installed. If I have one computer with another display card, for example, an S3 Virge

card, I could simply specify "XSERVER = s3virge" under it's MAC address and the setting will take effect the next time the workstation is rebooted.

4.6.5. Finding the MAC address

The MAC address consists of six 8-bit hexadecimal numbers which uniquely identifies every NIC, including wireless adaptors. You can usually get the workstation's MAC address while the machine is booting up with PXE or EtherBoot. It displays the MAC address while requesting an IP address from the server. You can make it display this address for a longer period by unplugging the network cable. If you are using ISA network cards, you can also obtain the NIC driver name and IO address and interrupt of the workstation's NIC from the workstation screen using the same process.

If your workstation has Windows installed on it, you can also find the MAC address by typing **ipconfig /all** in a DOS window. If it has GNU/Linux installed, you can find it by typing **ifconfig** in a terminal. (You will need to be the user with administrator rights in Ubuntu or root in other GNU/Linux distributions).

For more information

For more information on how to configure thin clients in Edubuntu 6.06 LTS, see notes on how to configure settings for Edubuntu 6.06 LTS, see: <http://www.edubuntu.org/ThinClientConfig>

The latest release, Edubuntu 7.04, provides additional options for customizing the thin client behavior. They are documented in the *Edubuntu Handbook*, which is available in the Edubuntu System Help menu.

4.7. Installing a thin client network in Ubuntu 7.04

Installing LTSP on an Ubuntu/Xubuntu/Kubuntu system requires a good internet connection and some patience to download the chroot environment for the clients. If you are using a slow internet connection, you might want to leave this to run all night.

If you are using Xubuntu and tried to install LTSP with the Alternative Install CD, you probably got an error. If so, you will need to first delete the chroot environment at **/opt/ltsp** before following these instructions. See the section [If you got an error...](#) below.

Assuming that you have successfully installed Ubuntu, Kubuntu or Xubuntu, the **universe** and **multiverse** repositories should be added so that you can download software which isn't in Ubuntu's main repository. You can either use the graphical program **Synaptic** or the command line.

4.7.1. Adding repositories with Synaptic

Select **Gestor de Paquetes Synaptic** in the **Sistema** menu. In the Synaptic application, select **Configuración : Repositorios**. In the Repositorios dialog box, put check marks next to **Universe** and **Multiverse**, then click **Update**.

4.7.2. Adding repositories from the command line

To add the universe and multiverse repositories from the command line, open a terminal window and log in as the user with administrator rights:

```
sudo -i
    [enter the password]
nano etc/apt/sources.list
```

Add the lines:

```
deb ftp://archive.ubuntu.com/ubuntu/ feisty main restricted universe multiverse
deb-src ftp://archive.ubuntu.com/ubuntu/ feisty main restricted universe multiverse
```

If using version 6.10, replace “feisty” with “edgy”. For version 6.06, use “dapper”. For version 5.10, use “breezy”.

Then update the list of available packages:

```
apt-get update
```

4.7.3. Installing the LTSP Server:

If not already the user with administrative rights, you will need to log in:

```
sudo -i
    [Enter password]
```

Then install the LTSP server:

```
apt-get install ltsp-server-standalone
```

Then install and configure the LTSP client image so it will be placed in the **/opt/ltsp** directory and ready for the clients to use when they connect to the server at bootup.

```
ltsp-client-setup
```

This script will download over 100MB of programs from the internet and install them in the chroot environment being constructed at **/opt/ltsp**. If you have a slow internet connection, be prepared for a very long wait.

4.7.4. If you get an error...

Unfortunately, this script doesn't have very good error recovery, and there is no easy way to correct the installation if something goes wrong. If your internet connection breaks or an error arises while installing, the script will stop. The only way to safely recover is to delete the chroot environment at **/opt/ltsp** and start over from scratch. If you aren't the user with administrator rights, first log in:

```
sudo -i
```

Then delete the chroot environment for your clients:

```
rm -rd /opt/ltsp
```

Then start over:

```
ltsp-client-setup
```

4.8. Thin client networks for old computers with Debian 4.0r0⁴⁸

Here are step-by-step instructions to set up a LTSP 4.2 server for a thin client network of old machines containing 32MB of RAM or less. Old 486s, Pentium Is and Pentium IIs with little RAM won't function well with the standard GNOME or KDE desktop used in most GNU/Linux distributions. You can't expect the kind of performance found in new clients, but you can dramatically improve performance in low-memory machines by using a minimal installation of GNU/Linux with X-Windows and a light windows manager such as FluxBox, IceWM or Xfce. These instructions are for setting up a thin client which allows the user to select the windows manager, but you may want to only install one windows manager depending on the memory in your thin clients. Thin clients with 12MB of RAM can probably only handle FluxBox (or 8MB of RAM with network swapping enabled). Clients can run IceWM with as little as 16MB. (Xfce will also run at 16MB, but it isn't recommended.) With 20MB or more, clients can handle Xfce (and even GNOME without most panel options enabled.) With 24MB or more, clients can run a minimal installation of GNOME.

These thin clients will be able to run standard word processors, spreadsheets and web browsers. Their multimedia capabilities, however, will be very limited, although most machines with 20MB RAM or more should be able to play sound.

Probably any GNU/Linux distribution can be used to build a thin client network for low-memory clients, but Debian was chosen because it is a system designed for building minimal systems and adding only the needed parts. Slackware would also be a good choice, although it requires more experience to maintain. In addition, many of Slackware's tools haven't been translated to Spanish and Portuguese.

Note: If trying to install an LTSP server with Debian 3.1, see this [how-to](#). For some odd reason, these instructions didn't work for me using Debian 3.1.r6, because an error was generated when trying to install a base system without selecting a desktop. If you encounter this problem, try using an earlier release of Debian 3.1.

4.8.1. If installing a mult-boot system in the LTSP server

If you want to install more than one operating system on your server's harddrive, you should probably repartition your harddrive before installing Debian. You will need to create an additional partition for Debian and a swap partition (if you don't already have one). The easiest way to do this is to use a Live CD with a disc partitioner such as **gparted**.

4.8.2. Get the Debian 4.0 installation CD/DVDs

Download the Debian 4.0 [Network Install CD](#), which is only 180MB and burn it to a CD. The following instructions are for installing using the Network Install CD. If you don't have an internet

⁴⁸ These installation instructions are based mainly upon two sources: Carlos E. Morimoto, "Terminais leves com o LTSP - Atualizado para o LTSP 4.2", 8 Dec 2006, <http://www.guiadohardware.net/guias/17/printall.php>; "How-To Install LTSP 4.1 in Debian 3.1 Sarge & Etch: A Step-by-Step Guide for the Beginner", revised 26 Sep 2006, <http://wiki.ltsp.org/twiki/bin/view/Ltsp/Debian>.

connection where you will be installing your LTSP server, then you will need to obtain the first Debian 4.0 [installation DVD](#) or the first 6 installation CDs.⁴⁹ In addition, download the LTSP CD which contains all the files that you will need for the LTSP installation at <http://ltsp.mirrors.tds.net/pub/ltsp/isos/>

4.8.3. Installing the Debian Operating System

1. Insert the installation CD (or DVD) and reboot your computer. If the computer doesn't boot from the CD, reboot and press F2, ESCAPE or whatever key is used to enter the BIOS in your computer. Set the CD as the first device in the boot order.
2. At the first screen, enter "installgui" to use the graphical installer.
3. If Debian will be the only operating system on your harddrive, let Debian automatically partition your harddrive. If you want to put more than one operating system on your harddrive or create a special setup with multiple partitions, you will need to manually edit the partition table.

Setup the root (/) partition first. Make selections as follows:

- Use "Ext3 file system".
- Format the partition: "Yes"
- Mount point: "/"
- Write down the root partition's ID# - i.e., /dev/hda6. You will need this information later.

Next setup the /home and swap partitions.

4. The Debian base system will then be installed.
5. Choose to install GRUB on the the master boot record (MBR) of the harddrive.
6. After Debian reboot, you will need to setup the time. If you plan to run Windows on the same machine, then don't choose UTC (Coordinated Universal Time), otherwise it is recommended to use UTC.
7. Set a root password, which is the password that you use to administer the LTSP server. Make sure to use a mixture of uppercase, lowercase, numbers and symbols if your thin client network will have internet access or it will have users who might be curious enough to try and crack the system. (Yes, students in classrooms will try to do this.)
8. If the server will have internet access, choose the mirror to a repository where additional software can be downloaded. Generally it is a better idea to chose an FTP mirror from your country or a nearby country, but some the mirrors in Latin America are extremely slow. If you aren't sure if the mirrors in our country are fast, the safest bet is to use the mirror "ftp.egr.msu.edu" from the United States. If you don't have internet access, just choose your installation CDs as your repository.

Apt-get, which is Debian's downloader and installer, will then connect to the mirror and update the sources list.

⁴⁹ You only need to download the CDs which contain the programs which you need. Go to <http://atterer.net/jigdo/jigdo-search.php> and enter the name of the program and your computer's architecture. For instance, if you want to install IceWM on a 32bit Pentium machine, search for "icewm_i386".

9. Do NOT choose any additional packages for installation. Installation of files will be completed.
10. During setup of the mail system, accept all defaults.

4.8.3.1. Install X-Windows

After Debian finishes installing, log in with the username and password that you created. Then switch to root to install all the additional software:

```
su
```

Enter the root password

At this stage Debian has no graphic capabilities, so you need to install X-Windows:

```
apt-get install x-window-system
```

Allow the x-server to autodetect your video hardware. It may have trouble identifying correctly your type of mouse and mouse port. In that case, you will need to choose the type of mouse and the port. For the correct settings, see these [configuration examples](#) in the X.org manual.

Chose the **MEDIUM** option for selecting your monitor's characteristics.

A windows manager is needed in order to be able to use windows and menus inside X-Windows. Here are instructions to install 3 windows managers (FluxBox, IceWM, and Xfce), so that users of the thin clients can choose their windows manager when they log in. If you don't want to give users that choice, only install one of the windows managers. In addition, a desktop manager is needed so that users can login. If you want your users the option to select their language and windows manager, install **gdm**. If you only want them to be able to enter their username and password, install **xdm**, which doesn't offer any options.

```
apt-get install icewm fluxbox xfce gdm (remove the unwanted programs)
```

If you want to use gdm, you will need to configure it by selecting "gdm", not the default "xdm."

You will also need a text editor so you can edit configuration files. If you want command line text editor that runs in a terminal window, install **nano** for a simple text editor and **vi** or **emacs** for an advanced text editor. For an X-Windows text editor which has a graphical user interface (GUI), install **xedit** for systems with little memory or **gedit** for systems with more memory.

```
apt-get install nano vi emacs xedit gedit (remove the unwanted programs)
```

You will also need to chose a file manager. Midnight Commander (**mc**) is a basic file manager which runs inside a terminal. For a GUI file manager, chose **Nautilus** for systems with more memory or **Thunar** for systems with less memory.

```
apt-get install mc nautilus thunar (remove the unwanted programs)
```

It may also be helpful to install a web browser so you can search on the internet in case you run into trouble setting up your LTSP server. Unfortunately, Mozilla FireFox 2 is not very stable in GNU/Linux and frequently crashes. The Seamonkey web browser, which is called "iceape" in Debian, is more reliable and uses less memory. The Dillo web browser is another option for people who want a minimal browser which uses almost no memory. Unfortunately Dillo's rendering of web pages leaves much to be desired and it doesn't support most extensions.

```
apt-get install mozilla-firefox iceape dillo (remove the unwanted programs)
```

Now start the xserver:

```
startx
```

If X-Windows is configured to work correctly with your hardware, you should enter the X-Windows desktop. If there is a problem and you are returned to the command line prompt, you will need to change the X-Windows configuration and try again. Generally the problem is either the video driver or the mouse type or mouse port. To reconfigure X-Windows:

```
dpkg-reconfigure xserver-xorg
```

After reconfiguring, run **startx** again. If it still doesn't work, you may have to edit the file **/etc/X11/xorg.conf**. For more information about editing the X-Windows configuration file, see [X.org documentation](#) or ask in the [Debian forums](#).

If you installed **gdm**, it needs to be configured so that so that root can login with gdm. It is very helpful for the network administrator to be able to login as root, especially when sitting down on any client computer. At the prompt enter:

```
gdmsetup
```

Inside the GDM setup dialog box, select the "Security" tab, then check "Allow local system administrator login", then click "Close".

Finally, remove the installation CD/DVD and reboot your server to make sure that all changes are applied:

```
reboot -n
```

4.8.4. Installing and configuring the LTSP server

The first step to setting up an LTSP server is to assign a static IP address to your LTSP server. Open a terminal window and log in as root:

```
su
```

Make a copy of the original **etc/network/interfaces** file in case you need to restore it later.

```
cp /etc/network/interfaces /etc/network/interfaces-original
```

Obtain your current IP address. At the prompt, enter:

```
ifconfig
```

On the second line of the listing for eth0, look for the current IP address of your server. Here is an example:

```
inet addr: 10.0.1.13
```

The IP addresses in `/etc/network/interfaces` file must match your current address. Use your favorite text editor to open `/etc/network/interfaces`.

```
#####
# /etc/network/interfaces

# The loopback network interface
auto lo
iface lo inet loopback

# The primary network interface
allow-hotplug eth0
iface eth0 inet static
    address 192.168.0.100    # IP address of your LTSP server
    netmask 255.255.255.0    # Do not change
    broadcast 192.168.0.255  # Change first 3 triplets of IP address
    gateway 192.168.0.1      # Your router's address-usually ends with 1

#iface eth0 inet dhcp

# end of file
#####
```

Change the “address” to match the address of your server. Change the first 3 triplets of the “broadcast” address to match the first 3 triplets of your server's address. Change the first 3 triplets of the gateway to match the first 3 triplets of your server's address. If your server's address is 10.0.1.13, then make the following changes:

```
address 192.168.0.100 => address 10.0.1.13
broadcast 192.168.0.255 => broadcast 10.0.1.255
gateway 192.168.0.1 => gateway 10.0.1.1
```

Save the new file as `/etc/network/interfaces`. Restart your networking so the new copy of your interfaces file will be used:

```
ifdown eth0
ifup eth0
```

Then download and install the debian packages needed by LTSP to operate a thin client network. The DHCP (Domain Host Configuration Protocol) server assigns IP addresses to the clients during bootup. The TFTP (trivial File Transfer Protocol) is used to transfer files from the server to the clients during bootup. The NFS (Network File System) server allows the clients to use files over the network. Perl is a language interpreter which is needed to run the **ltspadmin** and **ltspcfg** programs to setup and configure LTSP. To install all these packages:

```
apt-get install nfs-kernel-server dhcp3-server atftpd libwww-perl
```

During the ensuing installation, when the `dhcpd3-server` is being installed, you will be asked "What network interface should the DHCP server use?". Enter "eth0".

4.8.5. Installing and configuring LTSP

Download the LTSP installation package:


```
apt-get install ltsp-utils
```

Start the LSTP setup program by entering:

```
ltspadmin
```

The ltspadmin menu is counterintuitive. You will need to use the second option before the first option.

1. Select "Configure the installer options".
2. At the prompt "Where to retrieve packages from?", accept the suggested default web site.
3. Accept the [/opt/ltsp] installation directory.
4. For both HTTP and FTP proxy, press [Enter].
5. Answer [Y] to continue. You will be returned to the main menu.
6. Select "Install/Update LTSP Packages".
7. On the next screen the names of the available LTSP packages will be downloaded from the internet.
 1. Select [A] to install all of the packages.
 2. Then hit [Q] to close the menu.
8. Answer [Y] to install. The files will be downloaded and installed.
9. Select "Configure LTSP" from the main menu. Ltspadmin will check to see if all the necessary files have been installed. Hit [Enter].
10. Next,
 1. "Show the status of all services" by hitting [S]. Some of these services will be started in the next step.
 2. Hit [Enter] to return to the previous menu.
11. Choose "Configure services manually" by hitting [C].
12. Step through each category. Enter [Y] to all suggested choices:
 1. Accept runlevel=2 for your Debian installation.
 2. Choose which network interface to use: "eth0"
 3. If you installed **gdm** instead of **xdm**, then ignore the error listing xdm as missing. If you did install xdm, during the xdmcp installation, answer [N] to "disable graphical logon on server". If you chose [Y], then your computer will boot to the command line prompt and you will have to type "startx" to start X-Windows.
13. Finally, enter [Q], [Q] to quit ltspadmin.

4.8.6. Configuring the DHCP server

The most difficult part of setting up an LTSP server is to configure correctly the DHCP server, so that the thin clients are assigned IP addresses correctly when they bootup.

A sample DHCP configuration file was created by the LTSP installation at **dhcpd.conf.sample**. It is for reference only and probably won't run without modification.

Navigate to the `/etc/dhcp3` directory and save the original configuration file:

```
cd /etc/dhcp3
cp dhcpd.conf dhcpd.conf-original
```

4.8.6.1. Dynamic IP addresses in the thin clients

If you want the DHCP server to dynamically assign IP addresses to the thin clients each time that they bootup, then use the following file as a model:

```
#####
# /etc/dhcp3/dhcpd.conf
#
# FOR LTSP WORKSTATIONS WITH DYNAMIC IP ADDRESSES
#
# (1) assignment of dynamic IP addresses to 10 workstations;
# (2) workstations assigned addresses xxx.xxx.xxx.101 to xxx.xxx.xxx.110;
# (3) server assigned IP address xxx.xxx.xxx.100 during Linux
#     installation.
#
# How to Edit this File:
# (1) IP addresses requiring change are marked "Change IP";
# (2) IP file format = xxx.xxx.xxx.yyy;
# (3) replace all IP addresses with your IP address;
# (4) obtain your specific IP address information from dhcpd.conf.sample
#     file created when LTSP was installed;
# (5) end each line with a ";" except after a parenthesis;
#     keep your "{    }" straight;
#     use "#" to prevent interpretation of text on the line beyond "#".
#
## Beginning of file

# - In Debian 4.0, or any version of Debian with dhcp3-server >= 3.0.3,
#   the "next-server" statement is needed or Etherboot will walk in
#   circles saying "No IP address". To activate, uncomment the line.
next-server          192.168.2.100;      # <--Change IP

ddns-update-style    none;
default-lease-time    21600;
max-lease-time        21600;
option subnet-mask    255.255.255.0;
option broadcast-address 192.168.2.255;  # <--Change IP
option routers        192.168.2.1;      # <--Change IP
option domain-name-servers 192.168.2.100; # <--Change IP
option domain-name     "ltsp";          # <--Accept/Change
option root-path       "192.168.2.100:/opt/ltsp/i386"; # <--Change IP
option option-128 code 128 = string;
option option-129 code 129 = text;

shared-network WORKSTATIONS {
```

```

subnet 192.168.2.0    netmask 255.255.255.0 {                # <--Change IP

    range dynamic-bootp 192.168.2.101    192.168.2.110;    # <--Change 2 IP's

    use-host-decl-names        on;
    option log-servers          192.168.2.100;                # <--Change IP
    if substring (option vendor-class-identifier, 0, 9) = "PXEClient"
    {
        filename    "/tftpboot/lts/2.4.26-ltsp-3/pxelinux.0";    #<--Check version
    }
    else
    {
        filename    "/tftpboot/lts/vmlinuz-2.4.26-ltsp-3";    #<--Check version
    }
    }
}

## End of file
#####

```

In the above file, the IP addresses must be changed to match the IP address of your server. In the example of the server with an IP address of 10.0.1.13, every instance of “192.168.2.100” would be changed to “10.0.1.13”. In the other addresses, the first three triplets would be changed from “192.168.2” to “10.0.1”.

In addition, check to see whether the path **/tftpboot/lts/2.4.26-ltsp-3/pxelinux.0** exists in your server's harddrive. The number **2.4.26-ltsp-3** is the version of the Linux kernel which the thin clients will use, but LTSP4.2update3 is using kernel 2.6.17.8. Change the path to match what is found on your harddrive. [Check the full path of /tftpboot/] Likewise, check the path **/tftpboot/lts/vmlinuz-2.4.26-ltsp-3** and change it to the kernel version found on your server's harddrive.

Save the file as **/etc/dhcp3/dhcpd.conf**. If necessary, assign the proper permissions, so the file can be read by all users:

```
chmod 644 /etc/dhcp3/dhcpd.conf
```

After modifying the **dhcpd.conf** file, the DHCP daemon must be restarted for the changes to take effect:

```
/etc/init.d/dhcp3-server restart
```

When DHCP server is restarting, the last message must display an **[ok]** tag at the end of the line. The first tag may say **[fail]** if the server is not started yet.

If there were gross errors in the configuration file, they will be listed on your console display. Check that the lines end in semicolons (;) and each opening bracket has a closing bracket {}. Most of the time, however, you will only know that the configuration file isn't valid, because the DHCP daemon fails to start.

Reboot the computer. (You can use **"reboot -n"** from the command line.) Then login as root. Open a terminal window and issue the command:

```
ltspadmin
```

Choose "Configure LTSP", [Enter], [S], [Enter]. You should find that all parameters are now

enabled and running. If you are using gdm, xdmcp will not be enabled:

```
xdmcp  YES   Enabled: no   Running: YES   xdm, gdm   Using: gdm
```

If one of the services is not enabled, check [Chapter 7: Troubleshooting](#) in the LTSP 4.1/4.2 manual.

4.8.6.2. Static IP addresses in the thin clients

It is easier to first get the network working with dynamic addresses, then later assign static addresses to each thin client if needed. To set static IP addresses, edit the following file.

```
#####
# /etc/dhcp3/dhcpd.conf
#
# FOR LTSP WORKSTATIONS WITH ASSIGNED PERMANENT IP ADDRESSES
#
# (1) assigns permanent IP addresses to 10 specific workstations;
# (2) workstation addresses assignable in range of xxx.xxx.xxx.101 to
#     xxx.xxx.xxx.110;
# (3) server IP address xxx.xxx.xxx.100 assigned during Linux
#     installation;
#
# How to Edit this File:
# (1) IP addresses requiring updating are marked as "Change IP";
# (2) IP file format = xxx.xxx.xxx.yyy;
# (3) replace all IP addresses with IP addresses
#     obtained from your dhcpd.conf.sample file installed by LTSP;
# (4) assign each workstation a different name;
# (5) each host workstation must also have an individual MAC address;
#     obtain the MAC address from /var/log/syslog while that specific
#     workstation is attempting to boot;
# (6) clone additional workstations as needed, assigning each a different
#     IP address between xxx.xxx.xxx.101 and xxx.xxx.xxx.110;
#     Note: each workstation has 2 parentheses "{ }" associated with it!
# (7) names of the workstations must also be entered in */etc/hosts* file;
# (8) remember to end each line with ";" except after parenthesis;
#     keep your "{ }" straight;
#     use "#" to prevent interpretation of text on the line beyond
#     the "#";
# (9) If you need to pass parameters on the kernel command line to a
#     workstation, you can do it with option-129. In order for Etherboot
#     to look at option-129, you MUST have option-128 set to a specific
#     value. The value is a special Etherboot signature of
#     'e4:45:74:68:00:00'.
#
#     Add these two lines to the each host entry that needs special
#     parameters:
#         option option-128      e4:45:74:68:00:00;          # Do NOT change
#         option option-129      "NIC=ne IO=0x300";          # An example
#####

# In Debian 4.0, or any version with dhcp3-server >= 3.0.3,
# the next-server statement is needed or Etherboot will walk in
# circles saying "No IP address". To activate, uncomment the line.
next-server          192.168.2.100;          # <--Change IP

# Uncomment the following option line if your boot rom contains the
# modification for using REQUIRE_VCI_ETHERBOOT. This option initiates
```

```
# the Vendor Class Identifier of "Etherboot":
# option vendor-encapsulated-options 3c:09:45:74:68:65:72:62:6f:6f:74:ff;

ddns-update-style          none;
default-lease-time         21600;
max-lease-time             21600;
option subnet-mask         255.255.255.0;
option broadcast-address   192.168.2.255;      # <--Change IP
option routers             192.168.2.1;       # <--Change IP
option domain-name-servers 192.168.2.100;     # <--Change IP
option domain-name         "ltsp";           # <--Change/Retain
option root-path           "192.168.2.100:/opt/ltsp/i386"; # <--Change IP
option option-128 code 128 = string;
option option-129 code 129 = text;

subnet 192.168.2.0 netmask 255.255.255.0 {    # <--Change IP
    range 192.168.2.101 192.168.2.110;       # <--Change 2 IP's
    use-host-decl-names  on;
    option log-servers   192.168.2.100;      # <--Change IP
}

host ws101 {
    fixed-address      192.168.2.101;        # <--Change IP
    hardware ethernet  00:30:bd:1e:d9:e2;    # <--Change MAC
    filename           "/tftpboot/ltsp/vmlinuz-2.4.26-ltsp-3"; #<--Check version
}

host ws102 {
    fixed-address      192.168.2.102;        # <--Change IP
    hardware ethernet  00:0d:dd:a2:a0:25;    # <--Change MAC
    filename           "/tftpboot/ltsp/vmlinuz-2.4.26-ltsp-3"; #<--Check version
}

## End of file
#####
```

Change the IP addresses and check the file paths as done with the static dhcpd.conf file.

Notice that individual clients have been given the names “ws101” or “ws102”. Make up names which make sense for your organization and are easy to remember. Some schools give their computers the names of famous scientists like “einstein” or famous figures in history like “bolivar”. In an office it might be better to call the computer by its location such as o233c3 (office 233 computer 3) or its division such as “accounting3”.

For each computer, a MAC address for its NIC and an IP address is listed. You can decide which IP address to use for each computer, but the MAC address must be the six hexadecimal numbers which uniquely identify each Network Interface Card (NIC). See section [4.6.5. Finding the MAC address](#).

4.8.7. Using ISA network cards

If you have an ISA network interface card in a client, it is recommended to change it for a PCI card if possible, since ISA cards can only operate at a maximum speed of 10Mb/s and are harder to configure. Many older computers built before 1995 only used ISA, so it may be the only option.

Just like a normal PCI NIC, ISA cards can use the EtherBoot program to boot over the network. Go to rom-o-matic.net and download the EtherBoot driver for your ISA card. If you can't find the chip for your card on the list, most ISA NICs are either NE2000 clones which use the "ne" driver or 3COM 509 clones which use the "3c509" driver. If you are unsure which driver you need, download both drivers and try them both. If neither work, then you probably need to find a different NIC.

Unlike PCI NICs, ISA NICs also require that two configuration lines be added to the DHCP configuration file so they will function correctly. Open the file `/etc/dhcp3/dhcpd.conf` using your favorite bare text editor (such as nano or gedit). Under the name of your client computer, add two lines:

```
option option-128 e4:45:74:68:00:00;
option option-129 "NIC=3c509 MOPTS=nolock,ro,wsiz=2048,rsiz=2048";
```

The number `e4:45:74:68:00:00` is a special code informing the DHCP server to use the options on the following line when operating the ethernet card. For a NE2000 clone, substitute "ne" for "3c509" and specify I/O port `0x300`. Below is a sample `dhcpd.conf` file for thin clients containing a 3COM 509 card and a NE2000 clone:

```
host ws101 {
    fixed-address      192.168.2.101;          # <--Change IP
    hardware ethernet  00:30:bd:1e:d9:e2;      # <--Change MAC
    filename           "/tftpboot/lts/vmlinuz-2.4.26-ltsp-3"; #<--Check version
    # for a 3COM 509 ISA card:
    option option-128 e4:45:74:68:00:00;
    option option-129 "NIC=3c509 MOPTS=nolock,ro,wsiz=2048,rsiz=2048";
}

host ws102 {
    fixed-address      192.168.2.102;          # <--Change IP
    hardware ethernet  00:0d:dd:a2:a0:25;      # <--Change MAC
    filename           "/tftpboot/lts/vmlinuz-2.4.26-ltsp-3"; #<--Check version
    # for a NE2000 compatible card:
    option option-128 e4:45:74:68:00:00;
    option option-129 "NIC=ne IO=0x300
MOPTS=nolock,ro,wsiz=2048,rsiz=2048";
}
```

4.8.8. Modifying the `/etc/hosts` file

Each machine which has an assigned name in the `dhcpd.conf` file should also be added to the `/etc/hosts` file, so it be properly recognized by NFS.

```
# /etc/hosts
# Configured for LTSP 4.2

# The first line is the LTSP server which is mapped to localhost:
127.0.0.1 server localhost

# Additional lines are the IP addresses and their corresponding
# names of the LTSP server and the clients:
192.168.2.100 server
192.168.2.101 ws101
```



```
192.168.2.102  ws102
```

Change the IP addresses and names to match your network. If you want to be able to address the clients over the internet and have assigned them to a domain such as **mydomain.com**, then also list the domain name, as well as their names:

```
192.168.2.100  server.mydomain.com  server
192.168.2.101  ws101.mydomain.com  ws101
192.168.2.102  ws102.mydomain.com  ws002
```

4.8.9. Configuring each client

Oftentimes client computers have special hardware and need to be individually configured to use that hardware. The configuration of the clients is set in the configuration file **/opt/ltsp/i386/etc/lts.conf**. There is a default section which lists the default configuration which every client on the network will use. In addition, each thin client can be individually configured. It can be individually identified by its assigned name or its MAC address. Put the assigned name or MAC address inside square brackets [], then follow it with the configuration for that client. All text following hash marks (#) are comments and will be ignored. Don't put comments in the same line as the [MAC address] or [assigned name]. Below is a sample **lts.conf** file:

```
#####
# /opt/ltsp/i386/etc/lts.conf
# Configuration file for clients using Linux Terminal Server Project (www.ltsp.org)

# This is the default configuration for all the thin clients:
[Default]
    SERVER            = 192.168.2.100      # Insert your server's IP
    XSERVER            = auto               # Auto-detect video driver and settings
    X_MOUSE_PROTOCOL   = "IMPS/2"          # PS/2 Microsoft Intellimouse
    X_MOUSE_DEVICE     = "/dev/psaux"
    X_MOUSE_RESOLUTION = 400
    X_MOUSE_BUTTONS    = 5
    USE_XFS             = N
    SCREEN_01          = startx            # Command to start X-Windows

# The configuration for client ws101:
[ws101]
    XSERVER            = sis               # Use the SiS video driver
    X_MOUSE_PROTOCOL   = "PS/2"           # Generic PS/2 mouse with scroll wheel
    X_MOUSE_DEVICE     = "/dev/psaux"
    X_MOUSE_RESOLUTION = 400
    X_MOUSE_BUTTONS    = 3

# Clients can also be identified by their MAC addresses:
[00:0d:dd:a2:a0:25]
    XSERVER            = vesa              # Generic VESA video driver
    X_MODE_0            = 800x600         # Set screen resolution to 800x600
#
#####
```

For more information about possible settings in the **lts.conf** file, see [Chapter 9. lts.conf entries](#) in the LTSP 4.1/4.2 manual.

4.8.9.1. Mouse configuration

Nowadays most mice are scroll mice, but if you are using older machines, you may not have scroll wheels or even a third button. In this case the mouse will have to be configured to emulate the third button. Below are some sample configurations for various types of mice.

For a PS/2 Microsoft Intellimouse with a scroll wheel:

```
X_MOUSE_PROTOCOL = "IMPS/2"
X_MOUSE_DEVICE   = "/dev/psaux"
X_MOUSE_RESOLUTION = 400
X_MOUSE_BUTTONS  = 5
```

For a PS/2 mouse with a scroll wheel:

```
X_MOUSE_PROTOCOL = "PS/2"
X_MOUSE_DEVICE   = "/dev/psaux"
X_MOUSE_RESOLUTION = 400
X_MOUSE_BUTTONS  = 3
```

For an Optical USB mouse with a scroll wheel:

```
X_MOUSE_PROTOCOL = "ImPS/2"
X_MOUSE_DEVICE   = "/dev/input/mice"
```

For a serial mouse with 3 buttons:

```
X_MOUSE_PROTOCOL = "Microsoft"
X_MOUSE_DEVICE   = "/dev/ttyS0"
X_MOUSE_RESOLUTION = 400
X_MOUSE_BUTTONS  = 3
```

For an older serial mouse with only 2 buttons:

```
X_MOUSE_PROTOCOL = "Microsoft"
X_MOUSE_DEVICE   = "/dev/ttyS0"
X_MOUSE_RESOLUTION = 400
X_MOUSE_BUTTONS  = 2
X_MOUSE_EMULATE3BTN = Y
```

4.8.9.2. Video card configuration

Generally GNU/Linux will be able to auto-detect your client's video card and its settings if the **[Default]** configuration in `lts.conf` contains the line `xserver = auto`, but sometimes auto-detection doesn't work properly and the video driver and setting have to be set manually for each terminal.

In recent years, embedded graphics processors in the motherboard have become more common. If you can't see a graphics card and can't identify a graphics chip in the motherboard, try the "i810" driver for Intel graphics processors, since they are the most common type of embedded GPU. Also try the "via" or "sis" drivers, which are also commonly used in embedded graphics today. If all else fails, try the generic "vesa" driver which is slower but will work with almost any graphics processor. Once you have a functioning screen, open a terminal window, enter as the root user and use the `lspci` to see what is attached to the PCI bus:

```
lspci
```

You should see something in the list which looks like a graphics processor. If you see nothing you probably have a AGP graphics processor. In this case, you can find it with the `lsapag` command:

lsagp

Once you have determined what processor you have, you can set the client to use it with the `xserver` command. For instance to use the “via” video driver:

XSERVER = via

The most common video drivers are “i810” for Intel embedded graphics, “radeon” for ATI Radeon, “r128” for ATI Riva 128, “nv” for nVidia, “sis” for both SiS embedded and add-in card graphics, “rendition”, “s3virge”, “tdfx” for Voodoo Banshee and Voodoo 3 e 4, “trident”, and “via” for the embedded Via Unichrome. For a complete list of available drivers and the cards which use them, see the [X.org manual](http://www.x.org/X11R6.8.2/doc/) (<http://www.x.org/X11R6.8.2/doc/>).

If you want 3D graphics, most of these drivers only support 2D graphics (except for the “radeon” and “i810” drivers). If you have an ATI or nVidia graphics card, you may be able to find proprietary 3D graphics drivers available for download from their websites.

If you have an ancient machine, you probably have an old ISA or VESA graphics processor, which can't be detected. In this case, the “vesa” driver is probably your best bet; or at last resort, the “vga” driver if you can live with 640 x 480 resolution and 8 bit color. Some of the old drivers used with the Xfree86 version of X-Windows may be better for old computers than the newer X.org drivers. For instance if you need to use Xfree86's old SVGA driver, specify:

XSERVER = XF86_SVGA

Occasionally, the proper settings for the video won't be detected, so they will have to also be manually set. Often when you see some sort of screen, but the video shakes, appears as multiple screens, or has incongruent lines interspersed, the video driver works, but has incorrect settings. The [X.org manual](#) has a large list of possible video settings, but the most useful are the screen resolution, refresh rates, and color depth.

4.8.9.3. Screen configuration

Common screen resolutions are 640x480 (VGA), 800x600 (SVGA), 1024x768 (XGA), 1280x1024 (SXGA), 1400x1050 (SXGA+), 1600x1200 (UXGA), and 2048x1536 (QXGA). Today's laptops commonly have widescreen displays with a 16:9 or 16:10 ratio designed for viewing high definition video. In this case, the resolution is probably 1280x768, 1280x800 (WXGA), 1366x768 (WXGA), 1680x1050 (WSXGA), 1920x1200 (WUXGA), or 2560x1600 (WQXGA).⁵⁰

To set the screen resolution:

X_MODE_0 = 1024x768

To set the vertical refresh rate of the monitor:

X_VERTREFRESH = 85

To set the horizontal refresh rate of the monitor:

X_HORIZREFRESH = 100

Generally it is only necessary to set the vertical refresh rate and not set the horizontal refresh rate.

⁵⁰ For a complete list of screen resolutions, see: http://en.wikipedia.org/wiki/Display_resolution

Be careful when setting the refresh rates, since some monitors can be damaged by setting the refresh rate too high. It is best to look your monitor's model number up online to find the vertical and horizontal refresh rates suggested by the manufacturer. If you can't find any stats for your monitor, modern monitors should be able to support a 90 Hertz vertical refresh rate at 1024x768 resolution, but monitors from a decade ago may only be able to support 60 Hertz at 800x600 resolution.

To set the number of bits in the color depth:

```
X_COLOR_DEPTH = 16
```

8 bits yields 256 possible colors, 16 bits yields 65,536 colors, 24 bits yields 16,777,216 colors, and 32 bits yields 4,294,967,296 colors. 24 bit and 32 bit are known as “true color” and are considered necessary for photo editing where it is necessary to display the full gradations of the color spectrum. Unfortunately, 24 and 32-bit color use a lot more bandwidth on your network and requires more powerful graphics processors in the clients. 16-bit color is recommended for normal use since it provides adequate graphics with less bandwidth and processing. At 8-bit color depth, some graphics may appear distorted or strange, but 8-bit color may be necessary for using older graphics processors with limited memory.

By multiplying the screen resolution by the number of color depth bits, then dividing by 8192 to convert to kilobytes, you can roughly estimate the memory requirements for a GPU to hold one screen of data in its memory. Of course a modern GPU needs a lot more memory than to just store one screen at a time, but the calculation shows how color depth and resolution settings can greatly increase the load on the GPU and the bandwidth needed on the network.

Minimum kilobytes of memory needed in graphics processors at various resolutions

Color Depth	640x480	800x600	1024x768	1280x1024	1600x1200
8 bit	300KB	469KB	768KB	1280KB	1875KB
16 bit	600KB	938KB	1536KB	2560KB	3750KB
24 bit	900KB	1406KB	2304KB	3840KB	5625KB
32 bit	1200KB	1875KB	3072KB	5120KB	7500KB

If using an 486 computer with a limited graphics processor and an ancient monitor, your settings might be something like:

```
XSERVER = vesa
X_MODE_0 = 800x600
X_VERTREFRESH = 60
X_COLOR_DEPTH = 8
```

4.8.9.4. Keyboard configuration

In order to correctly map the keys on a keyboard, the number of keys and country code has to be set. US keyboards generally have 101 keys, or 102 keys if they have a Windows key. In order to be able to type vowels with accents and letters like Ñ, they need to be set to US International with dead keys. Spanish and Latin American keyboards generally have 104 keys for the extra Ñ and Ç keys, or 105 keys if they have a Windows key.

For a US International keyboard with 102 keys:

```
XkbModel      = pc102
XkbLayout     = us_intl
XkbRules      = xorg
```

For a Spanish keyboard with 104 keys (no Windows key):

```
XkbModel      = pc104
XkbLayout     = es
```

For a Brazilian keyboard:

```
XkbModel      = ABNT2
XkbLayout     = br
```

4.8.9.5. Printer configuration

Generally, it is better to attach printers to the LTSP server, because they are installed like a normal local printer and any user of a client computer should be able to print to them. Nonetheless, printers can also be attached to thin client computers and be used by any user who has the proper permissions. If connecting a printer to a client, put the following setting in the `lts.conf`:

For a parallel port printer:

```
PRINTER_0_DEVICE = /dev/lp0
PRINTER_0_TYPE   = P
```

For a USB printer:

```
MODULE_01      = usb-ohci
MODULE_02      = printer
PRINTER_0_DEVICE = /dev/usb/lp0
PRINTER_0_TYPE  = S
```

After configuring `lts.conf` to recognize the printer, the printer drivers have to be installed in the server and it has to be configured to used as a network printer. First, download and install the necessary printing software:

```
apt-get update
apt-get install cupsys cupsys-bsd cupsys-client foomatic-bin gs-esp a2ps
```

In addition you will need to install the driver for your printer. Go to

<http://www.linuxprinting.org> and look up which print driver you need. For instance, for an HP InkJet printer, install the *hpijs* package:

```
apt-get install hpijs
```

If you want to share a printer between Linux and Windows machines, you will also need to install the **samba** and **smbclient** packages. Read this [how-to](#) for more information.

Then the printer must be configured, but this depends on your windows manager. In GNOME, use the command **add-gnome-printer**. In KDE, run the command **Kaddprinterwizard**. In a light windows managers like IceWM and FluxBox, you may need to use the **lpadmin** command. Enter **man lpadmin** for more information and see the CUPS documentation. (If using a distribution

based upon Red Hat or Fedora, use the commands **printconf-gui** or **printconf-tui**.)

In the printer configuration program, select the option to add a network printer. Create a queue for your printer. Make up a queue name and select a “JetDirect” as the printer type. Then enter the IP address for the thin client which has a printer connected to it. Set the port number to 9100. A second printer should use port 9101, a third printer should use 9102, and so on.

4.8.9.6. Activating sound

If a thin client has its own sound processor and speakers, it should be able to play audio. In order for sound to function on the clients, a sound server will need to be installed on the LTSP server and sound drivers installed in the LTSP chroot environment for the clients. Unfortunately, LTSP only functions well with the OSS sound drivers, which is older and more limited compared with ALSA, the default sound drivers for the Linux 2.6 kernel. The OSS sound drivers are installed by default in LTSP at `/opt/ltsp/i386/lib/modules/2.6.17.3-ltsp-1/kernel/sound/oss`. (The kernel version on your computer may be different.)

Likewise, LTSP works best with the oldest and most limited sound server, eSound (ESD). Arts (the default sound server in KDE) won't function at all in LTSP and NAS has only limited functionality. Although you can experiment with ALSA and NAS, it is best to stick with OSS and eSound despite their limitations.

OSS is already included in the LTSP chroot environment by default, but eSound needs to be installed in the server. Open a terminal, log in as root, and issue the command:

```
apt-get install esound
```

Then enable sound in the clients by editing the `lts.conf` file. If you want all the clients to have sound capabilities, add the following lines under the `[Default]` section:

`[Default]`

```
SOUND           = Y
SOUND_DAEMON    = esd
VOLUME          = 80
SMODULE_01      = sound
SMODULE_02      = auto
```

If you only want to enable sound on specific clients, then you will need to add these lines to the configuration for each client, rather than putting them under the `[Default]` section:

`[ws101]`

```
SOUND           = Y
SOUND_DAEMON    = esd
VOLUME          = 80
SMODULE_01      = sound
SMODULE_02      = auto
```

If you want ensure a quiet computing environment, set the `VOLUME` setting to a lower number and disable access to the sound mixer and volume adjuster so users can't turn up the volume. (In FluxBox and IceWM, these are not install by default).

Generally, LTSP will correctly auto-detect the sound driver to use if `SMODULE_02` is set to “auto”, but you may have to manually set the driver for the client. For instance, if an add-in Creative Ensoniq sound card is installed in `ws101` and the Sound Blaster Live PCI is installed in `ws102`, then the “`es1371`” and “`emu10k1`” sound drivers needs to be specified in the **lts.conf** file for these clients, respectively:

```
[Default]
    SOUND           = Y
    SOUND_DAEMON    = esd
    VOLUME          = 80
    SMODULE_01      = sound
    SMODULE_02      = auto
[ws101]
    SMODULE_01      = sound
    SMODULE_02      = es1371    # sound driver for Creative Ensoniq
[ws102]
    SMODULE_01      = sound
    SMODULE_02      = emu10k1   # sound driver for Sound Blaster Live PCI
```

Today most motherboards include an embedded sound processor, rather than add-in sound card. If you have an Intel chipset on your motherboard, your sound driver is probably “`i810_audio`”. For a SiS chipset, try “`sis7019`”. For a VIA chipset, try “`via82cxxx_audio`”. For just about any type of chipset including nVidia's nForce, try “`ac97`”. You can often discover what type of sound card you have by using the **lspci** command.

If the `lspci` command doesn't show a sound processor, you might have an older ISA sound card. Open the CPU and look for the sound processing chip on the ISA add-in card. If it has a Cristal cs423x chip, then use the following configuration:

```
SMODULE_01 = sound
SMODULE_02 = cs4232
```

ISA Sound Blaster cards require that the IO address and interrupt be specified:

```
SMODULE_01 = sound
SMODULE_02 = uart401
SMODULE_03 = sb io=0x220 irq=5 dma=1
```

Unfortunately, sound won't always function properly on the clients. Some applications will be incompatible with OSS and eSound, which are out-of-date and not very good at handling more than one sound stream. XMMS is probably the multimedia player which works best with these drivers, yet is light enough to run on any system. For clients with more memory, try Kaffeine which has a nicer interface than XMMS. For online audio chat, try GAIM. To install these programs:

```
apt-get install xmms kaffeine gaim
```

Kaffeine will require a large number of KDE dependencies be installed, just as gaim requires GTK+ libraries, so don't install these programs unless you need them.

Unfortunately, sound on some clients may prove impossible to implement or be very poor in quality. In this case, the only option is play sound on the speakers of the server. Playing all sound on the server's speakers creates a cacophonous computing environment and is clearly undesirable in most situations. This solution, however, may work in environments where there are only a few

clients that can't play sound and they are all bunched close to the server. It also might be desirable in situations such as a classroom lecture where everyone should be listening to the same audio track at the same time.

In order for users to play audio on the server's speakers, they will need permission to access the server's files **/etc/dsp** which creates the audio and **/dev/mixer** which controls the audio volume, balance, and other settings. Enter as root and grant these global permissions:

```
chmod 666 /dev/dsp
chmod 666 /dev/mixer
```

Then remove the sound configuration settings from the `lts.conf` file for those clients which you don't want to play sound locally. If you don't want any of the clients to be able to play sound locally, then remove the sound configuration settings from the `[default]` section.

4.8.9.7. Booting a client in text-mode

Sometimes it is necessary to use a client in only text-only mode from the command line. This is especially useful when trying to debug a problem, such as bad X-Windows settings, or when working with computers with limited memory. GNU/Linux is a powerful operating system even without a graphical user interface. Many sysadmins prefer to run their servers in text-only mode because it is more stable and more efficient (especially when remotely administering the computer through SSH). To boot into a text-only shell:

```
SCREEN_01 = shell
```

In shell mode, the user can switch between multiple logins by pressing `Ctrl + Alt + 2` (or some higher number). If you just want to bootup to debug a problem as the root user, use:

```
RUNLEVEL = 3
```

Normally the client would run the command `startx` when it hits runlevel 5, but by setting the runlevel to 3, runlevel 5 is never executed.

4.8.10. Allowing remote login

The configuration file for the `gdm` login manager is `/etc/gdm/gdm.conf`. The easiest way to edit this file to allow for remote logins is to run the **gdmsetup** program as root:

```
gdmsetup
```

Select the "Remote" tab. Change "Remote logon disabled" to "Plain". Then click "Close".

4.8.11. Enabling local storage devices

Local device support has improved dramatically with LTSP 4.2 which uses the `fuse` and `udev` modules to automatically recognize and mount apparatuses which are capable of being unplugged such as USB flash drives and USB harddrives or having their media removed such as IDE CD-ROMs, USB CD-ROMs, and floppy disk drives. The `udev` module auto-detects devices when plugged into the USB port, while the `fuse` module allows file systems to be mounted when users aren't logged in as root.

Although these devices can be laboriously mounted each time that they are plugged in or media is

inserted, it is far better to use the udev and fuse utilities to automatically detect them and make and icon for them automatically appear on the desktop, so they can be easily accessed.

Fuse has now been included in the standard Linux kernel since version 2.6.14, so you already have it if you installed Debian 4.0. To verify that the fuse module is installed and loaded in your kernel, use the command:

```
modprobe fuse
```

In addition, the fuse utilities, fuse libraries, and Perl for X-Windows are needed. To install these, open a terminal window, log in as root, and issue the command:

```
apt-get install fuse-utils libfuse2 libx11-protocol-perl
```

Now verify that fuse is automatically loaded on bootup. Use the **less** command to see the contents of the /etc/modules file, which lists every module which is loaded on bootup.

```
less /etc/modules
```

If you don't see “fuse” in the list of modules, add it with the command:

```
echo 'fuse' >> /etc/modules
```

Now you will need to create a configuration file for fuse, which tells it to allow users other than root to mount file systems. Issue the command:

```
echo 'user_allow_other' > /etc/fuse.conf
```

In order that all users will have permission to access to local devices, they must be added to the group “fuse”. The adduser command can be used to add users to the group. For instance, if you want to add user “jose” to the group “fuse”:

```
adduser jose fuse
```

Now go to <http://ltsp.mirrors.tds.net/pub/ltsp/utls/> and download the package **ltsp-server-pkg-debian_0.1_i386.deb** and install it:

```
dpkg -i ltsp-server-pkg-debian_0.1_i386.deb
```

Once installed, enable local device in the configuration file **/opt/ltsp/i386/etc/lts.conf**, by adding the lines “**LOCAL_STORAGE = Y**” and “**MODULE_01 = ohci-hcd**” under the **[Default]** section. For example:

```
SERVER          = 192.168.2.100      # Insert your server's IP
XSERVER         = auto              # Auto-detect video driver and settings
X_MOUSE_PROTOCOL = "IMPS/2"         # PS/2 Microsoft Intellimouse
X_MOUSE_DEVICE  = "/dev/psaux"
X_MOUSE_RESOLUTION = 400
X_MOUSE_BUTTONS = 5
USE_XFS         = N
SCREEN_01       = startx            # Command to start X-Windows
LOCAL_STORAGE  = Y
MODULE_01     = ohci-hcd
```

“ohci-hcd” is a universal driver which works for almost all USB devices, but it doesn't support USB 2.0, which is substantially faster. If you have USB 2.0 ports and need faster speed, use the “ehci-hcd” driver in place of “ohci-hcd”.

After the clients are rebooted, they should be able to use local storage devices. If you have

problems, read this explanation at <http://www.ltsp.org/twiki/bin/view/Ltsp/LTSP-42-LocalDev>.

4.8.12. Installing EtherBoot on the local harddrive

Ideally, thin clients should be booted from PXE or EtherBoot installed in the motherboards' BIOS or burned on an EPROM on the ethernet card. Unfortunately, this is not always possible or very easy to do. It takes special equipment to burn EPROM chips, and loading EtherBoot into the motherboard's BIOS is tricky business. For this reason, many people resort to simply booting the thin clients from the floppy or CD drive, but that solution can be problematic. Not only is booting from the floppy and CD slower, but also these medium can be easily popped out by the user and get lost. Furthermore, users gets annoyed because the etherboot floppy or CD is occupying a drive which they want to use. In this case, the best solution is to install EtherBoot on the harddrive of the client.

If you want to run the thin client on a computer which also runs Windows and choose the operating system at boot up, see these instructions <http://wiki.ltsp.org/twiki/bin/view/Ltsp/Debian> under the section “Minimal Hard Drive Installation”. If you want to install the thin client on a computer that also has another version of GNU/Linux installed on the harddrive, then see the instructions at <http://www.guiadohardware.net/guias/17/printall.php> under the section “Usando um HD para boot dos clientes”.

4.8.13. Activating network swap

Swap is space in the harddrive where memory can be temporarily stored when the computer runs out of space in the RAM. Swap allows computers to multitask more easily, since the memory from one program can be temporarily saved, while another program is loaded into the memory. With swap, computers can run with less RAM (albeit swap is much slower than normal memory). Diskless thin clients, however, have no swap space, since there is no local harddrive to save to. LTSP 4.2 includes an option to implement swap via the network, so that the swap for each client is saved on the server's harddrive.

With network swap activated, an LTSP client can run with as little as 8 MB of RAM. Many old 486s have 8MB of RAM, so they can be resurrected as functional thin clients. It may even be possible to use a 386 as a thin client provided that it has a good enough graphics card.

To implement network swap, download the file **ltsp-server-pkg-debian_0.1_i386.deb** from <http://ltsp.mirrors.tds.net/pub/ltsp/utills/>, then install it as the root user:

```
dpkg -i ltsp-server-pkg-debian_0.1_i386.deb
apt-get -f install
```

Unfortunately, this package has “fuse-source” as a dependency, but fuse has been incorporated into the kernel so that “fuse-source” is no longer available as a normal package for download. To get around this dependency, you will need to download an empty package with this name and install it, so that the dependency will be fulfilled. You can download the empty fuse-source package at <http://www.guiadohardware.net/kurumin/download/fuse-source.deb>. Then install it:

```
dpkg -i fuse-source.deb
apt-get -f install
```

The ltsp-server package includes the program ltspswapd, which implements the network swap, but this service needs to be started and added to the list of services which are loaded during bootup.

```
/etc/init.d/ltspswapd start
update-rc.d -f ltspswapd defaults
```

In addition, the lts.conf file needs to be modified to use network swap. Open the file /opt/ltsp/i386/etc/lts.conf with your favorite text editor and add the following line under the configuration for each client which will use network swap:

```
USE_NBD_SWAP = Y
```

By default 64MB of swap space will be created for each client inside the directory /var/spool/ltspswap in the server's harddrive. You can verify that the network swap is being used with the ls command:

```
ls -lh /var/spool/ltspswap/
```

You should see something like the following:

```
total 129M
-rw----- 1 root root 64M 2007-05-23 19:09 192.168.0.11.swap
-rw----- 1 root root 64M 2007-05-24 10:08 192.168.0.12.swap
```

5. Improving multimedia capabilities in a thin client network

The chief drawback of thin client networking is the poor performance of multimedia. Unlike most of the processing which is efficiently handled by the server's CPU, most of the video and sound processing is passed down the network to the thin clients, which are often woefully-underpowered machines. Makers of new thin clients often skimp on multimedia processors to save costs, because most business and governmental users of thin clients generally don't need to play high resolution MPEG4 video or 3D games. In the past, thin clients were often designed without multimedia ports since it was assumed that they wouldn't be needed. Internet phone and video conferencing have only recently become practical for many businesses and governments.

Likewise, older graphics and sound cards often aren't up to the task of handling today's multimedia. Most old computers resurrected as thin clients were designed when DVDs didn't exist and games didn't need to crunch through millions of floating-point operations per second just to create the latest 3D wonderlands from ID Software and Rockstar Games. According to one estimate 70-80% of thin clients are made with old computers, which are relatively expensive and difficult to upgrade. They use older AGP, PCI or even ancient ISA ports can't handle the torrents of data in modern multimedia.

In recent years, however, thin clients are being increasingly designed to handle stereo sound and 32 bit color, 3D and high resolution video. If looking to buy new thin client computers with multimedia capabilities, see IT Week's [recent review](#) of higher-end models with these capabilities.

Even if the thin clients do have adequate graphics and sound processors, the standard 10/100 Megabits-per-second ethernet doesn't have enough bandwidth to handle the multimedia streams being pumped through its wires. The thin client server, which often doesn't even have a graphics card, contributes to the problem by first decompressing audio formats like MP3 or video formats like MPEG4, then pumping these much-larger audio and video streams onto the network for the clients to process. A single client playing an MP3 file will require roughly 1.2 megabits per second to be transmitted over the network cables. If 10 users in a 30 client network are playing MP3 files at the same time, 12% of the available bandwidth in a standard 100 Mb/s network will be filled just by audio. Even at this level of usage, the latency of the network will be higher and it will take longer for packets to reach their destination. If all 30 users decide to play an MP3 file at the same time, the latency can become unacceptably high with noticeable delays between pressing a key and seeing the results displayed on the client's screen. To avoid a network bottleneck, the connection between the server and the switch should be upgraded to 1000 Mb/s

The situation gets far worse when dealing with video. A single 640x480 video played at 24 frames per second requires that 112 Mb/s be sent from the server to the client (and if the video media is being accessed from the client, the compressed file is being sent from the client to the server at the same time). One small resolution video will take up more than the entire bandwidth in a 100 Mb/s network. Even if the entire network is upgraded to 1000 Mb/s, only a couple users

will be able to watch a small resolution video at a time, and it may effect the latency of the entire network. In this situation, video can become jerky with noticeable pauses as the client waits for the stream to arrive across a clogged network. If a single client try to play a high-resolution MPEG video or a first-person-shooter game like Doom IV at the same time, the entire network will grind to as standstill as the video saturates the ethernet lines. Even if the connection between the server and the switch is upgraded to 10,000 Mb/s, the network would still bog down if more than 2 or 3 clients tried to play DVDs or 3D games. The cost of a 10,000 Mb/s network is so prohibitively high, that it hardly makes sense in the first place.

Nonetheless, upgrading to 1000 Mb/s ethernet may be enough to provide for some limited multimedia. For instance, if a couple users will be watching low-resolution U-Tube videos or using Skype video phone at a time, that sort of multimedia may be possible over a normal thin client network. f you want more multimedia capabilities than that, then you should consider installing “hybrid” clients which run multimedia applications locally on the client side, while running the standard applications from the server-side. The other option is to identify the users who need multimedia and give them standard fat-client computers, while the rest of the users use thin-client computers.

None of the 12 British schools using thin client networks in the Becta study were able to adequately provide multimedia capabilities to their students through their thin client networks. In many cases the thin client vendors exaggerated the multimedia capabilities of the systems. Listening to their advice, the schools installed clients which weren't powerful enough or ethernet infrastructure which wasn't fast enough. Most schools in the study either didn't provide multimedia to their students or they added fat clients which were capable of running multimedia. There are a number of ways, however, to provide multimedia over a thin client network. Each approach has its drawbacks and demands more expensive hardware. Nonetheless, they will still reduce the administrative costs compared to standard fat clients, while lessening the environmental impact.

5.1. Six ways to improve multimedia performance:

5.1.1. Speed up the network

If the clients have decent graphics and sound cards, the bottleneck may be a slow ethernet connection which isn't capable of streaming the graphics and sound to the clients fast enough. In this case, consider upgrading from 10/100 to 1000 Megabits per second. The ethernet will only run as fast as the slowest component, so the server's network interface card (NIC), the client's NIC, and the switch have to all be 1000 Mb/s for the ethernet to run at that speed. In addition, the connecting cables should be Cat5e rather than standard Cat5 to run at the higher bandwidth. Even if you can't afford to upgrade the entire network to 1000 Mb/s, at the very least, upgrade the server's NIC and the switch to 1000 Mb/s, because that connection is the most likely bottleneck in the network.

5.1.2. Upgrade graphics and sound processors on the clients

Although it is expensive to install new graphics and sound cards on all the clients, it is cheaper than buying whole new clients. The integrated sound processors found in most of today's motherboards are perfectly adequate for most people, but for older motherboards it may be necessary to add a separate sound card. If buying a card for a GNU/Linux thin client, look for an OSS [compatible card](#),⁵¹ which are the default audio drivers used by LTSP 4.2.

The Intel integrated graphics which are found in roughly 40% of computers⁵² are famously low-watt sippers and equally famous for their inadequate multimedia performance. Although add-in graphics cards often suck 2 or 3 times more wattage, they also provide substantially better performance. If the clients use older PCI or AGP video, old video cards can be picked up relatively cheaply in used markets.

If looking for more environmental hardware, ATI video cards from 3 or 4 years ago were generally more energy efficient than competing nVidia cards. If buying a more recent graphics card made in the last couple years, however, nVidia processors are substantially more energy-efficient and offer more performance per watt. For instance, the top-of-the-line nVidia GeForce 7900 GTX uses 84.2 max watts, whereas ATI's competing Radeon X1900 XTX sucks 120.6 max watts.

If looking to buy new thin clients with adequate multimedia, consider machines with the Intel 945GM chipset whose integrated 950 Graphics Media Accelerator is advertised as being capable of handling the demanding graphics requirements of MS Vista. Its 82945G GMCH graphics chip only uses 22.6 max watts,⁵³ which is half the wattage of many low-end graphics cards. If buying a new add-in card for a low-medium quality client, the best choice is the S3 Chrome S25 or S27 which runs on less than 30 watts.⁵⁴ The most environmental option for high-end clients is the GeForce 7900 GT, which is identical to the GTX, but its clock is turned down 31% so it only consumes 48.4 watts. For energy use of different graphical processors, see this [list](#). If buying a video card for a GNU/Linux client, first check [LinuxQuestions](#) or the comprehensive list at [Linux-Drivers](#) for compatibility.

If attempting to upgrade a thin client for high graphics performance, it is not necessary to buy a new motherboard with PCIe x16 or x32, despite all the industry hype. Manufacturers are still making AGP cards for the older AGP motherboards. See [this review](#) of available cards. Although the PCIe x16 has four times more bandwidth than AGP x8, in real terms this doesn't translate into significantly better performance. Many tout PCIe because it is the platform for nVidia's Scalable Link Interface (SLI) and ATI's CrossFire which permit two identical graphics cards to work in concert, but this option is tremendously expensive and energy-wasteful, and provides diminishing returns for each

51 If you have a newer sound card, you may need to use the ALSA sound instead of OSS sound, although ALSA is more difficult to configure to work with LTSP. See [this list of ALSA compatible cards](#).

52 Tony Smith, "ATI lost graphics market share to Nvidia in Q3", 6 Dec 2006, http://www.reghardware.co.uk/2006/12/06/q3_06_graphics_market/.

53 "Intel 945G/945GZ/945P/945PL Express Chipset Family", Dec 2005, <http://download.intel.com/design/chipsets/designex/30750403.pdf>.

54 Justin Mann, "S3 Chrome S25 & S27 Technology Overview", *TechSpot*, 3 Nov 2005, http://www.techspot.com/reviews/hardware/s3_chrome/.

additional card.⁵⁵

5.1.3. Use “hybrid” clients which run multimedia applications locally

In “hybrid” clients, which are also called “chubby” clients, applications can be run on the client as well as on the server. Hybrid clients running multimedia applications locally will avoid clogging up the network to transmit those graphics and sound streams. If the video and sound files are stored on the client's local drives, then no information has to be sent over the network. Even if the multimedia files are stored on the server, hybrid clients substantially reduce the network traffic because the files are transferred in their compressed form to the clients.

The clients will need to have decent graphics and sound processors for this solution to work. To implement a hybrid client for multimedia, it needs to have a full operating system and the multimedia applications installed on the client's harddrive, so it can't be a “diskless” client using software such as Thinstation or 2X PXES. It is possible to implement a diskless hybrid client with LTSP that runs some applications locally, but the setup is extremely complicated. Moreover, the [LTSP wiki](#) reports that local audio and video players won't be able to play video and audio streams coming from the server, because they don't have proper access to server files. Unfortunately, implementing hybrid clients will increase your administrative costs, since it takes more time to maintain the clients with their own operating systems and local applications,

If you only want to run a couple application from the server, it may be worth considering application server software, which runs individual applications from the server, rather than the entire desktop. For instance, the [2X ApplicationServer](#) runs Windows programs on Windows, Linux or Mac clients. Games, movie editors, and multimedia players could be installed locally on the clients, while all other programs could be run with the 2X ApplicationServer.

5.1.4. Upgrade the server's CPU or add extra servers to speed up processing

Since most of the graphics and sound processing is handled in the clients, the server doesn't need a sound or graphics card. However, the server does effect the speed of multimedia, because its CPU is in charge of decompressing audio and video files. Likewise, many games heavily tax the server's CPU and memory. The multimedia performance may be improved by either upgrading the server's CPU and memory or by adding extra servers to the network.

Although gaming stations generally try to improve performance by speeding up the CPU's clock, it is a better idea to buy a second processor for your server (preferably a multi-core processor), rather than replace your existing processor with a faster clocked single processor. With multiple processors, the whole system won't get as bogged down and won't let one multimedia application or game hog all the server's resources.

Often it is a better idea to simply add more servers to the network, rather than

⁵⁵ Wlizzard, “NVIDIA Quad-SLI vs. ATI Crossfire”, 29 Apr 2006,
<http://www.techpowerup.com/reviews/NVIDIA/QuadSLI/1>.

going through the hassle of trying to replace processors and often motherboards in your existing server. On many networks, it is critical that they never go down, so it simply isn't an option to take the existing server off-line and spending a day installing a dual processor motherboard and second processor, plus reinstalling the operating system.

If adding more terminal servers to the network, make sure that the thin client network is configured to redistribute equally the processing load among the available servers. See [2.4. Scaling up your network](#).

5.1.5. Use monitor multiplying

Omni Technology Solution's [Desktop Multiplier](#) for SuSE 10 Linux allows up to 10 different users to use their own monitors, while sharing the same CPU. Likewise, ThinSoft's [BeTwin](#) for Windows allows up to 5 users to share the same CPU. While not really a thin client network, monitor multiplying has many of the same advantages of thin clients, yet also provides excellent multimedia performance. Hardware costs are lower because there is only one CPU, and administration costs are lower because there is only machine to install, patch, and backup.

Monitor multiplying provides better multimedia because graphics and sound are processed in the local computer. Since the monitors are connected directly to the back of the computer, there is no slow ethernet connection to slow down the transmission to the user. Each user has a separate PCI graphics card, so the video is fast. (The Desktop Multiplier allows two users to share dual head cards). The monitor cables are plugged directly into the graphics cards to provide unfettered access and faster transmission. Since multimedia applications generally tax the graphics processor much more than the CPU, one CPU should be able to handle the processing for a number of graphics cards at once. It is doubtful whether a single CPU could handle 10 people running Quake IV, but Novell reports that most people running SuSE Linux software in their test demonstrations didn't even notice that they were sharing a CPU with the Desktop Multiplier. Novell reported similarly good results after setting up 2205 SuSE Linux machines in 105 South African schools with the Desktop Multiplier.⁵⁶

Unfortunately, desktop multiplying is not scalable beyond a few users, nor can it be flexibly arranged. Each of the monitors have to be within close proximity of the CPU. Omni TS recommends that monitors be within a 5 meter radius of the CPU which is maximum length of most video cables. ThinSoft sells a 4.5 meter combo monitor and USB cable bundled in their [Buddy B-680](#) pack for BeTwin. The mice and keyboards are connected to USB cables and hubs, which are also limited in length.

The Desktop Multiplier can only provide audio to each user, if the keyboards or monitors have incorporated USB hubs, which allow USB headphones to be plugged in. In many Latin American countries, this hardware is not available for sale, or is extremely pricey. Therefore, all the users will forced to share the same set of speakers, which is possible since all the monitors are in close proximity, but it does create a cacophonous computing environment when a number of multimedia applications are running at once.

⁵⁶ "Novell South Africa Deploys 2,205 SUSE Linux Desktops in 105 Schools with Desktop Multiplier", Useful Corp, 2006, <http://userful.com/customers/case-study-omni-sa-web.pdf>.

Since the monitor multiplying software is proprietary, figure on paying high license fees (although they are less than buying operating systems for every fat client).

For a monitor multiplying solution that is scalable and can be flexibly arranged, consider Neoware's e140 thin clients with Matrox EpicA multi-display graphics cards.⁵⁷ Although the e140 doesn't promise the kind of multimedia performance of the Desktop Multiplier or BeTwin, it does reduce the costs by allowing multiple monitors to share the same thin client CPU.

5.1.6. Use NEC's [Virtual PC Center](#) (VPCC)

NEC has created innovative [US100](#) thin clients which each have their own graphics and sound processors capable of handling real time video and Voice over IP locally. With VPCC installed on the terminal server, multimedia files will be passed to the clients in their compressed form, so the network will not be bogged down by uncompressed video and sound streams. NEC claims that sound processing is actually more reliable than on a standard fat client because the US100 has a dedicated sound processor which isn't affected when the rest of the system slows down.

Unfortunately, VPCC with all the included hardware and software costs almost a thousand dollars per client--far more than a standard fat client. A Dual Xeon VPCC server for 20 users is priced at US\$19,500, while a 50 user server is a whopping US\$44,900. Meanwhile each client is priced at US\$349. At these prices VPCC should only be considered by businesses willing to pay through the nose for the better security and the lower administration costs of a thin client network, yet also need adequate multimedia.⁵⁸

57 "Neoware and Matrox Collaborate on Multi-Display Thin Clients", 14 Sep 2006, *DABCC*, <http://www.dabcc.com/article.aspx?id=2658>.

58 John Cox, "NEC's virtual desktop boosts thin client graphics", *Network World*, 30 Apr 2007, <http://www.linuxworld.com.au/index.php/id:956863388;fp:32768;fpid:1020267123>; David Needle, "NEC Fattens Thin Client Performance", 23 Apr 2007, <http://www.internetnews.com/ent-news/article.php/3673676>.

Appendix A: Downloading and installing software and burning CD/DVD images

Downloading software

Unfortunately, in Latin America, it is often easier to obtain pirated software worth thousands of dollars than it is to obtain free software which is gratis. The lack of internet access and slow download speeds are major barriers to obtaining and using free software.

In many Latin American cities, street venders will sell the latest Windows software for little more than the price of a blank CD or DVD. In the Andes, pirated software sells for US\$1.25 - \$2.50 per CD and S\$2.25 - \$5 per DVD. It is often possible to buy the latest versions of the major GNU/Linux distributions for the same prices. Unfortunately, specialized distributions like Edubuntu and K12LTSP, are generally not for sale and must be downloaded.

In order to download large files and whole CD images, it is best to use FTP (file transfer protocol) sites, rather than HTTP (hypertext transfer protocol) sites. FTP sites start with an address “ftp://”. The FTP protocol allows for breaking and resumption of downloads unlike the HTTP protocol. Many download managers such as GetRight claim to be able to resume broken HTTP downloads and to be able to download files in multiple parts at the same time, but errors often occur with HTTP downloads. An even better way to download your software is to use BitTorrent, which has built mechanism to check for errors while downloading. The original BitTorrent client is a flaky application which frequently crashes, so it better to use a clone such as [Ktorrent](#) or [Azureus](#).

If not using BitTorrent, use a download manager. In Windows, TrueDownloader and GetRight are decent GUI downloaders. One of the most reliable downloaders is [wget](#), a command line tool which runs in both GNU/Linux and Windows. It should be included by default in your GNU/Linux distribution, but it can be downloaded from the repository for your GNU/Linux distribution. If using Windows, download it [here](#).

To download a file from the internet, simply open DOS in MS Windows XP by going to **Start->All Programs->Accessories->System Symbol**. In GNU/Linux open a terminal. At the command line prompt, issue the command:

```
wget address
```

For instance, to obtain the Edubuntu 7.04 Classroom Server Add-on CD:

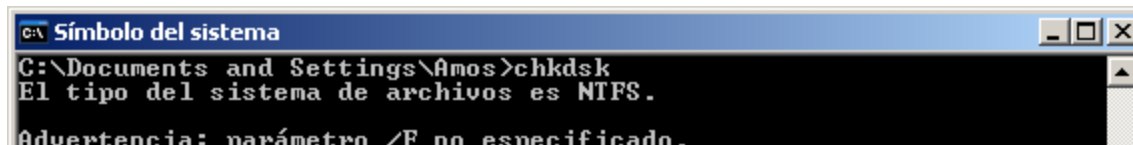
```
wget http://ftp.ale.org/mirrors/ubuntu-releases/edubuntu/feisty/edubuntu-7.04-server-i386.iso
```

If you ever want to stop the download, simply press the **Control** and **C** keys simultaneously to cancel the download. To resume a broken download, issue the command from the same directory:

```
wget -c address
```

Note that whole DVDs can not be download in Windows if the harddrive is using the FAT 32 file system, because FAT 32 only allowed for a maximum file size of 1024MB (1GB). Only

download DVDs in Windows if the file system is NTFS, which is what Windows NT/2000/XP/Vista use by default. You can check which file system is being used by issuing the **chkdsk** command in DOS. The first line after issuing the command will inform you which file system you are using:



If you need to go to a cybercafe to download files, go to a cybercafe which either has a download manager or allows you to install a download manager. Some cybercafes have locked down their systems so that nothing new can be installed.

If searching for a particular GNU/Linux distribution to download, go to www.distrowatch.com which provides a description of more than 350 GNU/Linux distributions and lists their web sites, download sites, and help forums. If you are searching for a particular free software application for Windows, Linux/UNIX, or Mac, go to www.sourceforge.net or www.freshmeat.com.

Burning CD/DVD images

Most GNU/Linux distributions use standard ISO CD/DVD image files which must be burned to a CD or DVD before they can be used to install GNU/Linux. CD/DVD image files can not be burned like normal data files. Once you have downloaded a CD/DVD image file (they usually end in **.iso**), open a CD/DVD burner program.

If you need a CD burner for Windows, you can download CDBurnerXP Pro for free. For GNU/Linux, the best CD/DVD burner is K3B, which you probably have if you are using KDE. The built-in CD/DVD burner in Nautilus for GNOME and xfburn for Xfce don't include options to burn CD/DVD images, so it is best to install K3B (or GnomeBaker). See the following section [Downloading and installing software in GNU/Linux](#).

To burn a CD/DVD image with Ahead Nero, simply double click on the image file. If the file ends in **.iso**, Nero will automatically detect that it is an image file and burn it correctly. If it is an ISO file, then you can simply add **.iso** to the end of the filename to get Nero to recognize it correctly.

For CDBurnerXP Pro 3, open the application. At the startup window, click on the first option:

Create a new Data CD-RW, Data-DVD-WR, Video-DVD, or create/burn an ISO image. You can also erase a disc or convert an ISO image.

Then under the **File** menu, select **Write Disc from ISO file...** In the dialog box which appears, look for the box **Select an ISO image to Write** and click the [...] button to select the ISO image file. After selecting the image file, click **[Write Image]**.

For the best reliability, burn CDs and DVDs at low speeds. Edubuntu recommends burning their Instalation CDs at x8 speeds. Most GNU/Linux instalation CD/DVDs have an option at bootup to

check whether the CD/DVD is free of errors. It takes 7-15 minutes to check each CD and use a program like MID5SUM to calculate an error checksum and see if it matches the expected value. It is more environmental to buy rewriteable CDs and DVDs for GNU/Linux installation CDs, since most of these CDs will be out of date within a year or two, so they are likely to be thrown away. In addition, rewriteable CD/DVD's can be reused in the case of bad downloads and bad burns.

Downloading and installing software in GNU/Linux

It is generally better to download GNU/Linux software from the repository of your particular distribution. In Debian or Ubuntu, use **apt-get** or **aptitude** from the command line or **synaptic** for a GUI (graphical user interface) application to properly download and install new software. These programs will check whether a software program is compatible with your existing installation and has any dependencies (relies on any other programs) which also need to be downloaded and installed. To use apt-get in Debian, open a terminal, change to the root user and issue the apt-get command:

```
su
[enter the root password]
apt-get install package-name
```

In Ubuntu/Edubuntu, use the **sudo** command instead of **su** and enter the normal user password:

```
su
[enter the normal user password]
apt-get install package-name
```

Generally, the package-name is the same as the name of the software, but you can use **aptitude** or **Synaptic** to search for the correct package-name.

For more information on how to configure and use apt-get, see this [short tutorial](#) or this [longer one](#). If you prefer using graphical applications rather than the command line, see [this easy guide](#) for using Synaptic.

In Red Hat, Fedora, or Mandriva, use **yum** or **up2date** from the command line to download and install programs. For **yum**, use:

```
su
[enter the root password]
yum -i package-name
```

For more information on how to configure and use yum, see [this tutorial](#) or [this longer one](#). Fedora and K12LTSP comes with a graphical application called **pirut** to download and install or update software. It can be found under **Applications → Add/Remove Software**.

Appendix B: Calculating costs and energy use

Whenever deciding which kind of thin client network to implement, costs become a critical factor. Of course, the most obvious costs are the hardware and the software, and every tallying must begin with this basic calculation. Below are some of the costs for thin client software:

Costs of Server Software:

Company	Software Title	Price	Platform
2X	ApplicationServer	\$695-\$15,250	Win
2X	LoadBalancer	\$449-\$1,895	Win
2X	ThinClientServer	\$595-\$10,395	Win
2X	ThinClientServer PXES Edition	gratis	Win
2X	TerminalServer	gratis	GNU/Linux
Microsoft	Windows Server 2003 R2 Standard (5 CALs)	\$999	Win
Microsoft	Windows Server 2003 R2 Standard (10 CALs)	\$1,199	Win
Microsoft	Windows Server 2003 R2 Enterprise (25 CALs)	\$3,999	Win
Microsoft	Windows Server 2003, 5 Client Access Licenses (CALs)	\$199	Win
Microsoft	Windows Server 2003, 20 Client Access Licenses (CALs)	\$799	Win
Microsoft	Windows Server 2003, 5 Terminal Services Client Access Licenses (TS CALs)	\$749	Win
Microsoft	Windows Server 2003, 20 Terminal Services Client Access Licenses (TS CALs)	\$2,979	Win
Citrix	Presentation Server 4.5	Contact Citrix	Win
Citrix	Presentation Server 4.5 Advanced 1 User Connection Pack	£162	Win
Citrix	Presentation Server 4.5 Enterprise 1 User Connection Pack	£209	Win
Citrix	Presentation Server 4.5 Platinum 1 User Connection Pack	£278	Win
Sun	Sun Ray Software 4	\$125 per client	Win/Linux/Solaris UNIX
NEC	Server Express5800/VPCC Virtual PC Server for 20 clients (includes the server hardware)	\$16,176	Linux
NEC	Express5800/VPCC Management Server	\$3,301	Linux

Free/libre/open source software can reduce the costs of software licenses substantially, however, it must be evaluated whether it really works for the needs of your organization. If it requires extra training to learn or is more difficult to use, that must be added into the calculation.

Often, the long-term and unseen costs far outweigh initial costs of acquiring the hardware and setting up the network. Sadly, many of these costs don't make it into the standard balance book, so they tend to be ignored. Below is a chart of all the potential costs which should be considered when thinking about setting up a thin client.

Costs to consider when calculating the Total Cost of Ownership (TCO)

Category	Examples of Costs
Acquisition and Procurement	<ul style="list-style-type: none"> • Administrative costs such as developing bid specs, evaluating proposals, gathering data, budgeting, and negotiating. • Researching and evaluating options such as upgrade, rebuy, lease, or purchase. • Contracts, tracking purchases, transfer and delivery. • Hardware (purchase or lease). Including personal computers (PCs), all peripherals, storage, networking, and other related equipment. • Spare systems and parts, annual supplies, and materials. • Software licenses.
Operations and Maintenance	<ul style="list-style-type: none"> • Administrative costs, including contract management, asset management, overseeing contractor services, a share of human resources, and other operating costs. • Vendor-contracted and/or in-house training of staff and IT personnel, product maintenance, and help desk support. • Information technology support such as database management, network management, and software management. • Retooling to accommodate new hardware and software. • Software and hardware upgrades over time. • Share of floor space, furniture, and other fixed office costs. • Internet and other network access costs. • Energy costs. • Training for IT staff and users. • Informal staff self-support of computer users. • Down time due to hardware/software malfunctions and/or user errors.
End-of-Life Management	<ul style="list-style-type: none"> • Administrative costs including asset management, documenting inventory, vendor contract procurement and management, and invoice payment. • Staging (removing and consolidating equipment). • Sanitizing hard drive and other storage media. • Testing and/or preparing for reuse, such as by reloading hard drive. • Providing follow-on support to employees or others purchasing used equipment. • Recycling/disposal fee and/or outsourcing fee. • Shipping. • Value of sold products and materials.

Source: "Total Cost of Ownership Guidance", 15 Mar 2006,
<http://www.federalelectronicchallenge.net/resources/docs/costofown.pdf>.

The costs which you should consider will vary greatly according to your type of organizations or businesses. For an organization which only have a couple computers, the initial cost of setting up a thin client and specialized knowledge to maintain it are too expensive to be worth the savings which a thin client network affords. Likewise, organizations which need most of their computers for graphical design or multimedia, probably won't save any money setting up a thin client network for the few computers which just handle standard processing tasks. On the other hand, organizations and businesses with hundreds of computers handling mundane computing tasks like word processing and data entry may reduce their costs substantially, especially the costs of maintenance and support.

Generally, the higher the costs of administering and maintaining a network, the more thin-client networks can reduce those costs. Nonetheless, for many organizations, these costs are not important. For instance, the owner of a cybercafe or the administrator of a telecenter who spends all day maintaining 15 computers, probably doesn't worry too much about having to spend an extra 20 minutes everyday administering the computers in the network, because he or she has to be watching the computers all day anyway. On the other hand, a business which pays for each tech support call can reduce its costs substantially with thin client networks.

One often overlooked factor is the cost of the electricity to run the computers in a network, and especially the greenhouse gases which electricity generation causes. Looking toward the future, energy costs will become an increasingly important factor due to rising prices and carbon taxes to reduce global warming. Many climatologists predict that global warming will be the biggest single threat to the continuing existence of humankind on the planet.

Servers have become energy hogs, and many companies such as Google are increasingly worried about their inordinate energy bills from the servers. Since servers are generally left on 24 hours in a day and sport large power supplies and multiple processors, they use substantially more energy than the standard client computer. Compare the amount of electricity used and carbon dioxide (CO₂) produced by different types of servers below.

Server Energy Usage

System	CPU clock	Avg. Watts	Idle (W)	Load (W)	Kilowatt-hours / month	Electricity cost / month (US\$)	CO2 / month (lbs)	Configuration (no monitor included)
2 Intel Xeon 5160 (new Core 2)*	3.0 Ghz		175	267	141,5	\$14,15	214,2	ATI ES1000 16MB integrated graphics, 74GB 10000RPM SATA HD, 4GB DDR2-677 FB RAM
2 Intel Xeon 5080*	3.73 Ghz		232	415	197,8	\$19,78	299,4	ATI ES1000 16MB integrated graphics, 74GB 10000RPM SATA HD, 4GB DDR2-677 FB RAM
2 AMD Opteron 285*	2.6 Ghz		178	322	152,4	\$15,24	230,7	ATI Rage XL 8MB integrated graphics, 4GB DDR-400 ECC RAM, 74 GB 10000RPM SATA HD
2 AMD Opteron 252†	2.6 Ghz	240	227	287	173,5	\$17,35	262,7	nVidia Quadro FX3000 graphics, 4GB RAM, 72GB 10000RPM SCSI-360 HD, 180GB 7200RPM SATA HD

*Tests by Sina Mohammadi and Achim Roos, "Intel Xeon and AMD Opteron Battle Head to Head", Tom's Hardware, 26 Oct 2006, http://www.tomshardware.com/2006/10/26/intel_woodcrest_and_amd_opteron_battle_head_to_head/page9.html.

†Test by Jem Matzan, "Computers, electricity, and you", 29 Dec 2005, <http://www.hardwareinreview.com/cms/content/view/33/29/>.

Assuming that servers run at full load 8 hours per day, 21 days per month, and are otherwise idle. Electricity costs based upon a Latin American average of US\$0.10 per kw/h. CO₂ production is based upon the US average of 1.514lbs of CO₂ per kilowatt of electricity. "US EPA E-Grid", 2002, EIA Electric Power Annual 2001, 2003, <http://www.epa.gov/cpd/pdf/brochure.pdf>. CO₂ equivalencies based on data from the U.S. Climate Technology Cooperation Gateway, <http://www.usctcgateway.net/tool/index.cfm>; "Electricity Prices for Households", Energy Information Administration, 28 Feb. 2007, <http://www.eia.doe.gov/emeu/international/elecprh.html>.

The amount of CO₂ per month is based upon a US averages of CO₂ per kilowatt-hour of electricity. In many Caribbean and Central American countries where electricity generation is exclusively from fossil fuels, the amount of CO₂ generated would be much higher. Since CO₂ is

the principal greenhouse gas which causes global warming, these numbers are worrisome. Anything that can be done to reduce the amount of energy which your computers consume helps avoid the droughts, violent storms and climatic change of global warming, and reduces the amount of people who will suffer its effects. If the network isn't used at night and on weekends, shutting down the server can save on these energy costs.

Even more critical are the energy costs of running the client computers on the network. Computers can vary widely in their energy consumption.

Energy costs for older computers

CPU Type	CPU (Mhz)	Off (W)	On (W)	Sleep (W)	Kilowatt-hours/month	Electricity / month (US\$)	CO2 / month (lbs)
Intel P3	733	3	32	22	6,0	\$0,60	9,0
Intel P3	1000	3	45	4	6,6	\$0,66	9,9
Intel P4	1300	4	64	5	9,2	\$0,92	13,9
Intel P4	1700	2	60	2	7,5	\$0,75	11,3
Intel P4	1800	3	79	4	10,1	\$1,01	15,3
AMD Athlon	1000	4	101	4	13,0	\$1,30	19,6
AMD Athlon	1300	3	93	3	11,5	\$1,15	17,4
AMD Athlon	1400	3	111	5	13,5	\$1,35	20,4

Assuming that computers are used 21 days in a month, left on 6.9 hours per day and actively used 3 hours per day—half of idle time is in sleep mode. For computer usage patterns, see Megan Bray, "Review of Computer Energy Consumption and Potential Savings", Dragon System Software, Dec. 2006, <http://www.dssw.co.uk>. For energy measurements, see: Judy A. Roberson et al. "Energy Use and Power Levels in New Monitors and Personal", Energy Analysis Department, University of California-Berkeley, July 2002, p. 21-23, <http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1567&context=lbln1>. Electricity costs based upon a Latin American average of US\$0.10 per kw/h. "Electricity Prices for Households", Energy Information Administration, 28 Feb. 2007, <http://www.eia.doe.gov/emeu/international/elecprh.html>. CO2 production is based upon the US average of 1.514lbs of CO2 per kilowatt of electricity. "US EPA E-Grid", 2002, EIA Electric Power Annual 2001, 2003, <http://www.epa.gov/cpd/pdf/brochure.pdf>. CO2 equivalencies based on data from the U.S. Climate Technology Cooperation Gateway, <http://www.usctcgateway.net/tool/index.cfm>.

Monitors are probably the single greatest user of energy within a computer. Compare the energy consumption of different types of monitors.

Monitor Energy Use

Monitor Type	Size	Off (W)	Deep Sleep (W)	On (W)*	On (W/in ²)
CRT	15"	0	3	55	0,58
	17"	0	2	58	0,47
	19"	0	2	86	0,55
	21"	0	2	100	0,52
	All CRT	0	2	75	0,53
LCD	15"	2	2	16	0,17
	17"	2	2	31	0,25
	18"	1	2	53	0,38
	All LCD	2	2	27	0,23
All Monitors		1	2	53	0,45

Source: Judy A. Roberson et al. "Energy Use and Power Levels in New Monitors and Personal", Energy Analysis Department, University of California-Berkeley, July 2002, p. 21-23, <http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1567&context=lbln1>.

The relative cost of electricity and environmental impact of that electricity varies widely across Latin America and the Caribbean. If you don't know the cost of electricity in your area, use the following chart:

Energy and the Environment in the Americas

Region	Human Development Index world ranking	Traditional fuel consumption (% of total energy requirements)	Price of kilowatt-hour of electricity (US\$)	Electricity consumption per capita (kilowatt-hours)		MDG carbon dioxide emissions per capita (metric tons)		Share of world total CO2 emissions (%)	Ratification of Convention on Climate Change	Ratification of Kyoto Protocol
Year		2002	2004	1980	2002	1980	2002	2000		
Antigua and Barbuda	60			984	1438	2,2	4,7		•	•
Argentina	34	3,2	0,04	1413	2383	3,8	3,5	0,6	•	•
Bahamas	50			4062	6084	38,1	6,7		•	•
Barbados	30	6,3	0,19	1333	3193	2,7	4,6		•	•
Belize	91			370	713	1,3	3,1		•	•
Bolivia	113		0,07	292	485	0,8	1,2		•	•
Brazil	63	26,7	0,09	1145	2183	1,5	1,8	1,3	•	•
Canada	5	4,6	0,07	14243	18541	17,2	16,5	1,9	•	•
Chile	37	12,5	0,09	1054	2918	2,5	3,6	0,3	•	•
Colombia	69	16	0,08	726	1019	1,4	1,3	0,3	•	•
Costa Rica	47	24,9	0,07	964	1765	1,1	1,4		•	•
Cuba	52	33,8	0,14	1029	1395	3,2	2,1	0,1	•	•
Dominica	70			149	1197	0,5	1,5		•	•
Dominican Republic	95	7,2	0,15	582	1326	1,1	2,5	0,1	•	•
Ecuador	82	17,5	0,13	423	943	1,7	2	0,1	•	•
El Salvador	104	32,8	0,13	336	665	0,5	1		•	•
Grenada	66	0	0,22	281	1913	0,5	2,3		•	•
Guatemala	117	58,6	0,16	245	660	0,6	0,9		•	•
Guyana	107	42,5	0,06	545	1195	2,3	2,2		•	•
Haiti	153	45,5	0,06	58	73	0,1	0,2		•	•
Honduras	116	52,8	0,05	259	696	0,6	0,9		•	•
Jamaica	98	6,5	0,19	834	2640	4	4,1		•	•
Mexico	53	8	0,09	999	2280	4,2	3,7	1,8	•	•
Nicaragua	112	47,9	0,14	363	496	0,7	0,7		•	•
Panama	56	17,8	0,12	930	1654	1,8	2		•	•
Paraguay	88	45,7	0,06	233	1129	0,5	0,7		•	•
Peru	79	20,6	0,11	579	907	1,4	1	0,1	•	•
Saint Kitts and Nevis	49				2619	1,2	2,8		•	•
Saint Lucia	76			504	1698	0,9	2,4		•	•
Saint Vincent and the Grenadines	87			276	1000	0,4	1,6		•	•
Suriname	86	3,3	0,13	4442	4447	6,7	5,1		•	
Trinidad and Tobago	57	0,4	0,04	1900	4422	15,4	31,9	0,1	•	•
United States	10	3,6	0,09	10336	13456	20	20,1	24,4	°	°
Uruguay	46	35,4	0,11	1163	2456	2	1,2		•	•
Venezuela	75	2,8	0,05	2379	3484	5,8	4,3	0,7	•	•
Developing countries		24,5		388	1155	1,3	2	36,9		
Least developed countries		75,9		83	106	0,1	0,2	0,4		
Arab States		18		626	1946	3,1	4,1	4,5		
East Asia and the Pacific		11		329	1439	1,4	2,6	17,6		
Latin America and the Caribbean		19,8	0,10	1019	1927	2,4	2,4	5,6		
South Asia		24,5		171	566	0,5	1,2	6,3		
Sub-Saharan Africa		70,6		434	536	1	0,8	1,9		
Central and Eastern Europe and the CIS		4,1		3284	3328	10,1	5,9	12,2		
OECD		4,1		5761	8615	11	11,2	51		
World		7,6		1573	2465	3,4	3,6	100		

Source: Human Development Report 2005, UN, pp 289-92, <http://www.sd.undp.org/HDR/HDR05e.pdf>; "Electricity Prices for Households", Energy Information Administration, 28 Feb. 2007, <http://www.eia.doe.gov/emeu/international/elecprh.html>.

Trying to calculate all the costs may prove unfeasible, but it is a good idea to try and keep at least some of the costs in mind when evaluating whether to switch to a thin client network.

Appendix C: The free software alternative

GNU/Linux, which is often referred to as simply “Linux”, is a “free software” operating system. Free software is a widely misunderstood concept and there is a lot of FUD (“fear, uncertainty, and doubt”) slung around term. In order to understand what is free software and why it has generated so much controversy, it is important to understand its origins and evolution.

Originally, most software was “free software” although it wasn't understood by that term. Companies like IBM which sold computers gave away software code for gratis as an incentive to buy their computers. They were so eager to keep software free, that they even took cases to court to prevent software from being patented. During the 50s - 70s, software code was passed around freely between institutions and there was little restriction on its use. The rise of the minicomputer in the late 70s, however, created a mass-market for software. Companies like Microsoft, Oracle and Autodesk, began selling compiled software and selling it in its binary form in shrink-wrapped boxes. Whereas in the past, people could easily study the code and add their own modifications, now they became passive consumers who had no rights and could be controlled by the code which they were prohibited from seeing.

Alarmed by how software was stripping rights from computer users, Richard Stallman, a brilliant programmer from MIT, quit his job in 1984 and started working on a free software clone of UNIX called GNU (**G**nu is **N**ot **U**nix). Stallman argued that everyone should be guaranteed the **4 fundamental freedoms** to 1) use the software for any purpose, 2) study the source code and adapt it for personal use, 3) distribute copies to help their neighbor, and 4) improve the software and distribute it. Thousands of idealistic programmers were so inspired by Stallman's message that they started contributing to the GNU project and a social movement was formed promoting free software. They produced thousands of programs under the General Public License (GPL), ensuring that anyone could freely use, copy, change, and distribute their software as long as they don't restrict others from having the same rights. By the early 1990s, they had almost finished creating a complete operating system except for the kernel, which is the central part in charge of interacting with the hardware and assigning resources to other programs.

In 1991, Linus Torvalds, a 19 year old Finnish student, started working on the kernel of an operating system for 386 computers as a hobby. Others dubbed the kernel “Linux” and combined it with the GNU software to create a complete operating system. The code was such high quality that companies such as SuSE, Red Hat, Mandrake, Cygnus, and Ximian were formed to commercialize free software and sell support and services for it. Stallman had always made clear that free software could be a commercial product and was called “free” as in “free speech,” rather than “free” as in “free beer.” Nonetheless, the idealist talk about user's rights and the confusion about the meaning of the word “free”, scared off many businesses. The movement was accused of being “socialist” and destroying the software business. To counteract this image and distance the movement from its idealist origins, a group began calling the software “open source” in 1998. They emphasized the commercial possibilities of the software and its superior development methodology which encouraged wide collaboration, reduced costs, and eliminated bugs. In the heady days of the internet boom, “open source” became the latest buzz word in the high tech

industry; and major tech companies such as IBM, SUN and Novell developed plans to capitalize on “open source”.

A bitter division developed between those who promoted “free software” as a means to effect social change and those who promoted “open source” for its practical and commercial benefits. People who speak Romance languages avoid this fight altogether by simply referring to it as “software libre” or “livre”, since there is no confusion between “gratis” and “libre”. In order to heal the breach, many now advocate the neutral term “FOSS” or “FLOSS” for “free/libre/open source software”. Whatever term is employed, avoid calling it “freeware”, since that is software which is gratis, but doesn't grant the right to see the source code, nor change the program. In many cases, freeware has special restrictions on copying and distributing as well.

Latin American governments promoting free software

Although the majority of Latin Americans pirate Windows software, a growing number of Latin American governments are promoting a free software alternative. Since 2001, São Paulo has created 158 telecenters using GNU/Linux to provide internet access to 250,000 people in poorer neighborhoods. The success of the telecenters convinced the Brazilian government to promote a plan to convert 300,000 machines in 6 ministries to GNU/Linux and promote the sale of lower-priced computers using Fenix Linux with the PC Conectado program. Venezuela was so alarmed by the way they were locked out of their computers by a US tech company during the national oil strike in 2002, that the Venezuelan government began a campaign to switch the government to free software so it would never again be held hostage by proprietary code controlled by foreign companies. In December 2004, Decreto N° 3.390 of Venezuela established a plan to migrate all public institutions to free software within 2 years. In September 2005, Peru passed a law prioritizing the use of free software in public institutions of the state. All of these measures have been undertaken despite the tremendous pressure of Microsoft, which threatened to sue the Brazilian minister implementing the migration plan to free software,⁵⁹ used the US ambassador to pressure the Peruvian government,⁶⁰ and used legal obstacles to hinder the Venezuelan initiatives.⁶¹ It appears that Ecuador is also turning toward free software. In December 2006, Rafael Correa had a meeting with Richard Stallman, the founder of the free software movement, in order to discuss how Ecuador could adopt a free alternative. This wave of government initiatives across Latin America suggests that there will be new opportunities for businesses and organizations which adopt free software, especially if they are looking for contracts with the government.

59 Pedro Cadina, "Microsoft: "Drug-Dealing Methods"", *Linux Journal*, 1 Jul 2004, <http://www.linuxjournal.com/node/7654/print>.

60 Agustin d'Empaire, "Microsoft's Big Stick in Peru", *Wired*, 27 Jul 2002, <http://www.wired.com/techbiz/media/news/2002/07/54141?currentPage=1>.

61 See comments of Oscar O. (21 Jun 2006) in "Venezuela and Free Software", Tux Magazine, <http://www.tuxmagazine.com/node/1000199>.

Quick stats about free software usage

- 78% of the 500 fastest supercomputers in the world use GNU/Linux or BSD.
- 58.9% of web servers use Apache.
- 75.1% of Domain Name Servers (DNS) use free software.
- 45% of email servers use free software (sendmail 42%, postfix 2%, exim 1%).
- Since April 2002, PHP has been the most popular web programming language.
- In June 2001, 35.7% of web servers used GNU/Linux or BSD. Five years later, 83% of businesses reported in a survey (November 2006) that their servers in new systems would use GNU/Linux.
- In 2004, 14% of large businesses reported used OpenOffice.
- In 2005, 64% of developers and administrators of databases reported using a free software database (MySQL, Firebird, PostgreSQL, etc.).
- 1.1 million developers work on projects using free software in North America.⁶²

Misconceptions about free software

1. Free software is gratis.

Free software doesn't have to be gratis, and some makers of free software charge money for their software, but they aren't selling a license granting the right to use the software. Rather they are selling the physical CD that it comes on and any services and support which they offer with the software. The price of CDs with free software are often quite cheap because anyone can make copies and give away the software for gratis, which drives down the price.

2. Free software is non-commercial.

Many of the best known free software programs are being developed by commercial companies who hope to use it to make a profit. They charge for services and support for the software, or they use it to sell hardware, or they sell proprietary software which runs on top of a free software program. Sometimes, companies pay programmers to work on free software because they want to gain credibility and a better reputation in a certain market, or because they need to use the software to run their businesses more efficiently. Today, most of top programmers on the Linux kernel, OpenOffice, Apache, MySQL, and GNOME are all paid by companies who have commercial goals.

3. Free software is lower quality and untrustworthy

Some free software is buggy and untested, just like some proprietary software, but studies of the some of the best known free software programs have shown it to have fewer defects in its code than most proprietary software. Studies found 0.09 defects per thousand lines of code (DTLC) in MySQL and 0.16 DTLC in the Linux kernel. In contrast, the industry average for proprietary software is 0.57 DTLC, which is 6 times higher than MySQL and 3.5 time higher than the Linux kernel.⁶³ A study of 438 software vulnerabilities found that free software responds to vulnerability

⁶² For more statistics about free software usage and studies, see: Amos Batto, "Los Beneficios del Software Libre para Bolivia", 28 Apr 2007, <http://www.ciber-runeta.net/BeneficiosSoftwareLibreBolivia.pdf>; David A. Wheeler, "Why Open Source Software / Free Software (OSS/FS, FLOSS, or FOSS)? Look at the Numbers!", revised 16 Apr 2007, http://www.dwheeler.com/oss_fs_why.html.

⁶³ Michael S. Mimoso, "Software experts find MySQL code exceptionally clean", Enterprise Linux, 18 Dec 2003,

reports 60% more rapidly than proprietary software.⁶⁴

4. Free software is harder to use than proprietary software

A decade ago, most free software did involve a high level of expertise to use, but today, many free software programs employ graphical user interfaces which are as easy to use as many proprietary programs. GNU/Linux distributions like Ubuntu, Xandros and Linspire are not any more difficult to learn to use than MS Windows. In 2002, a study found that tasks which took 41.2 minutes in Windows and MS Office, took 44.5 minutes in KDE and OpenOffice.⁶⁵ In the last 5 years, GNU/Linux and OpenOffice has gotten significantly easier to install and use, so there is good reason to suspect that a study today would find no difference in time. A 2005 study by the British government of 8 primary and secondary schools concluded: “Pupils advise that when they first used [free software] it was quite hard, but now they are used to it, they find it easier to use than Windows-based programs.”⁶⁶

5. Free software only works in GNU/Linux

According to SourceForge, a website that tracks free software development, there is more free software for MS Windows, than X-Windows, which is the graphical environment used by GNU/Linux. It lists 17,379 free software projects for Windows, 2062 projects for Mac OSX, and 8995 projects for X-Windows.⁶⁷ Many of the best free software programs such as OpenOffice, FireFox, AbiWord, MySQL, and Gnumeric are cross-platform and run just as well in Windows as GNU/Linux.

FLOSS (Free/Libre/Open Source Software) for MS Windows

For almost every proprietary program which runs in MS Windows, there exists a free software (open source) alternative. In order to replace the proprietary software on your MS Windows machine, here is a list of possible software replacements. For a more comprehensive list of every program available, see the [OSSwin Project](#). For Spanish speakers, see the comprehensive list at [CDLibre.org](#). If comparing costs between proprietary software and its FLOSS alternative, see this [list of software prices](#).

If you would like to download all these programs at once, [The Trinidad and Tobago Computer Society](#) has compiled the [WinOSS CD](#) with the latest versions of most of these programs. For Spanish versions of these programs, [CDLibre.org](#) offers a DVD and several CDs with most of these programs. If you just want a basic introduction to free software, try [The Open CD](#) (no Spanish version available).

http://searchenterpriselinux.techtarget.com/originalContent/0,289142,sid39_gci941817,00.html; Robert Lemos, “Security research suggests Linux has fewer flaws: Four years of research by a code-analysis firm finds that the latest open-source OS beats commercial software for quality,” CNet, 13 Dec 2004, http://news.com.com/Security+research+suggests+Linux+has+fewer+flaws/2100-1002_3-5489804.html.

64 Ashish Arora, et al., “An Empirical Analysis of Software Vendors’ Patching Behavior: Impact of Vulnerability Disclosure”, Carnegie Mellon, Jan 2006, http://www.heinz.cmu.edu/~rtelang/disclosure_jan_06.pdf.

65 John Blau, “Study: Linux nears Windows XP usability: Researchers studied how easily users could perform tasks using the two operating systems”, IDG, 4 Aug 2003, <http://www.computerworld.com/softwaretopics/os/story/0,10801,83708,00.html>.

66 “Open Source Software in Schools: A case study report”, British Educational Communications and Technology Agency (Becta), May 2005, p 12, <http://publications.becta.org.uk/download.cfm?resID=25908>.

67 SourceForge, accessed 7 Jun 2007, http://sourceforge.net/softwaremap/trove_list.php?form_cat=229.

<i>Software Category</i>	<i>Proprietary Programs (Cost in US)</i>	<i>FLOSS Alternative</i>	<i>Comparison</i>	<i>Platforms</i>
Web Navigator	MS Internet Explorer (\$0) AOL Netscape (\$0) Opera (\$0)	Mozilla Firefox	Internet Explorer is a security nightmare and should only be used when a webpage has been programmed to only work with Microsoft's proprietary extensions of the standard internet formats. Most spyware and other forms of malware has been designed to take advantage of the gaping security holes in Internet Explorer. According one test , an Internet Explorer user will receive 21 times more malware than a Firefox user.	Win, Linux, Mac
		SeaMonkey	SeaMonkey uses the same codebase as Firefox but is a complete suite that uses less memory and has more tools than Firefox, although it doesn't support as many extensions as Firefox.	Win, Linux, Mac
E-Mail	MS Outlook Express (in Windows XP: \$199, \$299) MS Outlook (\$109, in MS Office: \$399, \$499) Qualcomm Eudora (\$0, \$49.95) Corel WordPerfect Mail (\$29, \$35; in WP Office: \$99, \$299, \$399)	Mozilla Thunderbird	MS Outlook is a security hazard which can be a vector for dangerous scripts in email. Thunderbird doesn't have all the features of MS Outlook, but is much more secure, since it has built-in spam filters and doesn't allow dangerous scripts to run.	Win, Linux, Mac
		SeaMonkey Mail	SeaMonkey Mail is very similar to Thunderbird but supports a couple more advanced options.	Win, Linux, Mac
Internet Instant Messenger	AIM (AOL Instant Messenger) (\$0) MS Windows Live Messenger (\$0) Yahoo! Messenger (\$0) Jabber (\$0)	Gaim	Unlike the proprietary internet chat programs which can only communicate in their own chat protocol, Gaim can handle all protocols so you don't have to switch between programs if you want to talk to people using MSN, Yahoo, Google, IRC, ...etc. It even supports spell-checking.	Win, Linux, Mac
FTP Client	InternetSoft FTP Commander (\$29.95, \$49.95) Glub Tech Secure FTP (\$25)	FileZilla	A fully featured FTP client based on the PuTTY command-line tool. It is very useful for long uploads and downloads when you want to pause and later resume.	Win
		WinSCP	WinSCP is an FTP client also based upon PuTTY with a simpler interface than FileZilla.	Win
Peer-to-Peer (P2P)	EDonkey2000 (\$0) KaZaA (FileTrack) (\$0) Napster (\$0)	BitTorrent	For almost all the P2P networks, there are free software clients available. Use aMule for eDonkey networks, Gnucleus for Gnutella networks, and KCeasy for FileTrack networks. In place of Napster, use OpenNap . BitTorrent, however, is the best of the P2P clients in the opinion of many free software users. Many free software projects prefer that their software be downloaded by BitTorrent.	Win, Linux, Mac
Podcast Receiver	PodFeeder (\$0) nimiq (\$0) Doppler (\$0)	Juice	Juice is a handy program for receiving podcasts automatically from many different sources. Essential for people who follow the alternative news on the internet from shows like Democracy Now! and CounterSpin.	Win, Mac, Linux (in the future)
Internet Telephone	Skype (\$0, charge per call) Symantec pcAnywhere (\$99.95, \$199.95) Iready DigiPhone (monthly fee) VocalTec Internet Phone	Speak Freely	Speak Freely is difficult to configure, but if both the sender and receiver have it installed, they can talk to each other for free, unlike Skype which charges for each phone call. In order to use Speak Freely, both the sender and receiver need an IP number, which can be tricky if the IP number is automatically assigned and can change.	Win
Plain Text Editor	MS Notepad (in Windows XP: \$199, \$299)	Notepad2	Quite frankly MS Notepad is a very inadequate as a bare text editor. Notepad2 is far superior, yet maintains a simple design. Unfortunately Notepad2 like MS Notepad can only open one document at a time.	Win

<i>Software Category</i>	<i>Proprietary Programs (Cost in US)</i>	<i>FLOSS Alternative</i>	<i>Comparison</i>	<i>Platforms</i>
		Notepad++	Notepad++ has so many options that many programmers use it in place of the text editors found in Integrated Development Environments. It recognizes and properly highlights almost every programming language. A real delight to use, although the non-programmer probably won't ever need most of its options.	Win
		emacs xemacs	This programmable text editor that can do everything, including check your email and run LISP. It has a steep learning curve and is almost a culture within itself, but it can do some amazing things--it has accumulated a lot of functions over the last 25 years.	Win, Linux, Mac
Word Processor	MS Word (\$229, in MS Office: \$399, \$499) Corel WordPerfect (in WP Office: \$99, \$299, \$399) IBM Lotus Word Pro (in SmartSuite: \$281 per year)	OpenOffice.org Writer	OOo Writer is better than MS Word according to many reviewers. In my opinion, WordPerfect is slightly better than OO Writer, but WordPerfect is more liable to unexpected crashes. OO Writer runs in Windows, Linux/UNIX, and OS X, unlike MS Word and WP. It can export documents as PDF and saves in a text format, so documents can easily be recovered or exported. It exports to HTML better than any of the other major word processors. Its only major drawbacks are a lack of reveal codes like in WP and its non-intuitive search features which are designed for people used to UNIX regular expressions. OO Writer can also open and save in many formats including MS Word's DOC format.	Win, Linux, Mac
		AbiWord	AbiWord is small, fast word processor. The upcoming version 2.5 will support internet collaboration editing like Writely does. AbiWord runs on all platforms and can open and save in many formats including DOC format. Its major drawback is that occasionally the formatting on screen will appear out-of-whack until the screen is redrawn.	Win, Linux, Mac
Presentations	MS PowerPoint (\$229, in MS Office: \$399, \$499) Corel Presentations (in WP Office: \$99, \$299, \$399)	OpenOffice.org Impress	Impress is just as user-friendly as PowerPoint and creates nice presentations, but Powerpoint has a few more advanced options than Impress. Occasionally you will need to reformat imported PowerPoint documents in Impress.	Win, Linux, Mac
Spreadsheet	MS Excel (\$229, in MS Office: \$399, \$499) Corel Quattro Pro (in WP Office: \$99, \$299, \$399) IBM Lotus 123 (in SmartSuite: \$281 per year)	OpenOffice.org Calc	OOo Calc is just as good as the proprietary spreadsheets, although graph manipulation is slightly better in MS Excel.	Win, Linux, Mac
		Gnumeric	Gnumeric uses the R statistics language, so its statistical and scientific functions are better than those found in the proprietary spreadsheets. Its graph manipulation, however, is rather limited..	Win, Linux
Tax Accounting	Intuit TurboTax (\$9.95, \$39.95, \$59.95) H&R Block TaxCut	OpenTaxSolver (OTS)	OpenTaxSolver can calculate federal taxes for the US and Canada and the taxes for California, Massachusetts, New Jersey, North Carolina, Virginia, Ohio, New York, Pennsylvania, and Ontario. In the future, check the Tax Code Software Foundation which plans to have free software for preparing the 2006 US federal taxes.	Win, Linux, Mac
Personal Finance/ Accounting	MS Money (\$19.99 - \$89.99) Intuit Quicken (\$29.99 - \$79.99)	Grisbi	Grisbi is a personal accounting application developed by a French group which is easy to set up and use. It doesn't support double entry bookkeeping and some other types of advanced accounting.	Win, Linux, Mac
Business Finance/ Accounting	MS Small Business Accounting (\$149)	<i>Currently none</i>	In GNU/Linux, GnuCash offers more advanced accounting, but only preliminary attempts have been made	

<i>Software Category</i>	<i>Proprietary Programs (Cost in US)</i>	<i>FLOSS Alternative</i>	<i>Comparison</i>	<i>Platforms</i>
Accounting	Intuit QuickBooks (\$99.95 - \$3000)		to port it to Windows. SQL-Ledger is accounting software that can run on Windows web servers.	
ERP (Enterprise Resource Planning)	Oracle PeopleSoft ERP SAP mySAP ERP MS Project (\$599, \$999)	InfoSiAL FactualLUX	FactualLUX manages the accounting and all other kinds of data in the management of a business. The version for Windows XP is not yet stable. The Windows version should only be used in Windows NT and Windows 2000.	Win, Linux, Mac
Statistics	SAS SPSS Base (\$1599) Insightful S-PLUS	JGR (Java Gui for R) R Commander	JGR (pronounced as "jaguar") and R Commander are graphical user interfaces for the R statistics language, which is a free software implementation of S. Although the SAS and SPSS are nicer GUIs, many statisticians like R better than the languages which come with SAS and SPSS. In addition, Gnumeric provides an easy way to use R functions inside of a spreadsheet.	Win, Linux, Mac
Calender		Mozilla Sunbird	Despite the fact that Sunbird is in the early stages of development and still lacks a number of functions, its interface is very intuitive and easy to use.	Win, Linux, Mac?
		KOrganizer	KOrganizer has more options than Sunbird, but is a little more difficult to use and less pleasing visually, since it maintains a UNIX/Linux style interface in Windows.	Win, Linux, Mac?
PIM (Personal Information Manager)		KDE PIM	KDE PIM is not as easy to use as an integrated PIM, because it consists of two separate programs, KAddressBook y KOrganizer, that were migrated from KDE in Linux. They do not have a Windows-style appearance, but they do have some advanced functions like palm pilot synchronization.	Win, Linux, Mac?
Web Page Editor	MS FrontPage (\$199, in MS Office: \$399, \$499) Adobe Dreamweaver (\$399)	Nvu	Nvu is a web page editor with a nice user interface, but fewer options than FrontPage and DreamWeaver. Its table editing needs improvement and there is no option to see both the HTML code and the web page at the same time while editing. Nvu is prone to frequent crashes and still has a number of annoying bugs, but I still prefer Nvu to FrontPage, because it adds less garbly-gook to my html code. In GNU/Linux, many use Quanta Plus, but its interface is much less intuitive than Nvu.	Win, Linux, Mac
		OpenOffice.org Writer	Writer has a web page mode so you can edit web pages, but you can't see the HTML code, so it is rather limited in its web editing capabilities.	Win, Linux, Mac
PDF (Publishing Format)	Adobe Acrobat (\$299, \$449)	OpenOffice.org	Although there is not free software program for editing existing PDF documents like Adobe Acrobat, you can edit your documents in OpenOffice and save them as a PDF. OpenOffice PDFs support hyperlinks, but do not support forms and the other advanced features of Adobe Acrobat.	Win, Linux, Mac
		PDFCreator	PDFCreator converts documents in a print format such as postscript into PDFs. It doesn't support hyperlinks, forms, and other advanced PDF features	Win
		xpdf	Although the main xpdf viewer doesn't run under Windows, its programs to extract images from PDF files and to convert PDF files into postscript or text do run in Windows.	Linux, (Command Line tools: Win, Mac)
Desktop Publishing	MS Publisher (\$169, \$209, in MS Office: \$399, \$499) Adobe Pagemaker (\$499) QuarkXPress (\$749, \$1499)	Scribus	Scribus is fast approaching the utility of Pagemaker and has already bypassed Publisher, although it isn't as user-friendly. Before installing Scribus, make sure to first download and install Ghostscript for viewing postscript files.	Win, Linux, Mac
Simple	MS Paint (in Windows	OpenOffice.org	OpenOffice Draw is better than MS Paint by all measures.	Win,

<i>Software Category</i>	<i>Proprietary Programs (Cost in US)</i>	<i>FLOSS Alternative</i>	<i>Comparison</i>	<i>Platforms</i>
Graphics	XP: \$199, \$299)	Draw	It also supports basic diagramming. It's only drawback is its poor export quality to other image formats like png and jpeg.	Linux, Mac
Diagramming	MS Visio (\$199, \$499)	Dia	Dia lacks some of the advanced features of Visio, but will handle the diagram drawing that most people want. For its code size, it is an amazing program. Currently Dia can't open Visio files and there is no easy way to share files between Dia and Visio users.	Win, Linux, Mac
Advanced Graphics	Adobe PhotoShop (\$649) CorelDRAW (\$399) Corel Paint Shop Pro (\$99)	GIMP (GNU Image Manipulation Project)	Some people say that the GIMP is more difficult to use than PhotoShop, although it may just be that they are used to PhotoShop. In any case, the GIMP has the same graphical editing capabilities of the PhotoShop, although some things like red-eye removal are harder to do.	Win, Linux, Mac
Vector-based drawing	Adobe Illustrator (\$499) Corel PaintShop Pro (\$99)	InkScape	InkScape is a vector image editor. It doesn't support all the features of the proprietary SVG editors, but it is rapidly improving.	Win, Linux, Mac
Animation	Adobe Macromedia Flash (\$399, \$699) Corel Animation Shop (\$39) AutoDesk Maya Complete (\$1999)	Blender	Blender is a 3-D modeling program which can be used to create animations, although it is harder to use than Macromedia, especially for creating web page animations. It has steep learning curve, but you can make animated movies with it.	Win, Linux, Mac
		GIMP with extension (See above)	GIMP supports SVG animation with an extension, but is significantly harder to use than Macromedia.	Win, Linux, Mac
Computer Aided Drafting	AutoDesk AutoCAD (\$899, \$3995) RibbonSoft QCAD Professional (~\$31, ~\$44, ~\$287) MathSoft Pro/ENGINEER	RibbonSoft QCAD Community Edition	QCAD is a 2 dimensional drafting program and circuit board designer which is easier to learn to use than AutoCAD. Although it doesn't offer the 3-D modeling and some of the advanced features of AutoCAD, it will serve for most drafting needs. RibbonSoft has released a free software edition of its software which is the same as QCad Professional except for support for the scripting and polyline modules. QCad is widely available in Linux, but to use it in Windows, you have to download the source code and compile it with the Qt library which isn't free in Windows. Although other Qt programs for Windows such as Scribus are available for download, I have been unable to find a compiled version of QCad for Windows. If you have access to Qt in Windows, please compile it for the rest of us who can't afford Qt licensing fees.	Win, Linux
Photo Manager	Apple iPhoto (in iLife: \$79) Nero PhotoShow (\$39.99) Sonic Roxio PhotoSuite (\$29.95) Google Picasa (\$0)	<i>Currently none</i>	Picasa is decent <i>freeware</i> (not <i>free software</i>) for Windows. In GNU/Linux, F-Spot, gThumb and KSquirrel are nice photo managers, but they haven't been ported to Windows.	
Multimedia Player	RealNetworks RealPlayer (\$0, \$19.99) MS Media Player (\$0) Apple QuickTime (\$0, \$29.99)	VLC (VideoLAN Client)	VLC has a couple of novel features that no other media players support. As good as RealPlayer and Media Player for watching movies, it falls short as a music player. VLC doesn't support ripping, and its play list features aren't very user-friendly. It uses normal menus and buttons, unlike some annoying media players which try to imitate physical stereos and VCRs, but users who like skins may find its selection limited. If a video has multiple sound tracks, VLC won't always auto-select the correct sound track--you have to select it from the menu.	Win, Linux, Mac

Software Category	Proprietary Programs (Cost in US)	FLOSS Alternative	Comparison	Platforms
		MPlayer	The Hungarian answer to RealPlayer, but it doesn't have a GUI interface in Windows yet. Some free software advocates don't like it because it supports a lot of proprietary formats, but it will play just about every format imaginable.	Command line: Win; GUI: Linux, Mac
		MediaFrame	A nice Java-based media player, but it should be avoided since it supports Digital Rights Management, an industry plan to restrict your digital rights.	Win, Linux, Mac
Music Player	Nullsoft Winamp (\$0) Musicmatch Jukebox (\$0, \$19.95)	MusikCube	MusikCube is an excellent music player and ripper with a very intuitive interface and nice play list features. It supports MP3, but it uses Ogg Vorbis by default which is a superior sound format. MusikCube doesn't support "skins", which some may see as a drawback. Unfortunately its GUI is programmed in Visual Basic, so it isn't portable to other operating systems.	Win
Sound Editor & Mixer	Sony Sound Forge (\$69.95, \$199.96) Sony ACID (\$69.95, \$374.96) Steinberg Wavelab (\$149, \$649) Adobe Audition (\$349)	Audacity	Audacity is a well-designed and easy-to-use sound editor, but it doesn't have track indicators, so you can only do very basic multi-track mixing. There are better proprietary sound editing programs but they are priced beyond the reach of most amateur musicians and redubbers.	Win, Linux, Mac
Video Editor	Adobe Premiere (\$99, \$849) Apple Final Cut (\$299, \$1299) Ulead MediaStudio Pro (\$399.99) Avid Pinnacle Studio (\$69.99, \$99.99, \$129.99)	VirtualDub	There is no free software replacement for the proprietary movie editors, but VirtualDub is a handy video capture/processing utility designed for AVI video. It can read, but not write, MPEG 1 video as well. If you want a freeware movie editor, check out Zwei-Stein Video Editor .	Win
		CinePaint	CinePaint edits bitmap images for traditional movie formats which use frames.	Win, Linux, Mac
DVD player	InterVideo WinDVD (\$39.95, \$49.95) Orion DirectDVD (\$99, \$149) CyberLink PowerDVD (49.95, 59.95, \$69.95)	See VLC above.	VLC occasionally has problems with DVD menus and doesn't deal very gracefully with bad spots in DVDs, but it will play most movies just as well as proprietary DVD software. The big problem is that there are ridiculous legal restrictions on decoding MPEG formats and decrypting the CSS (Content Scrambling System). If you believe as I do that most forms of intellectual property are morally wrong or if you believe that you should have the legal right to watch a movie which you paid for, then watch movies with a clear conscience with VLC. If you believe that big media companies should have the right to charge you for the act of decoding and decrypting information in their proprietary formats, then don't use VLC.	Win, Linux, Mac
CD/DVD Burner	Nero (\$79.99) Sonic Roxio DigitalMedia Studio (\$69, \$99, \$149)	CDRDAO (CD Recorder Disk-At-Once)	CDRDAO is a command-line tool for burning CDs which runs in just about every platform. To use it requires creating a text file which contains information about how to burn the CD. Unfortunately CDRDAO can't burn DVDs and doesn't have a graphical interface. Burn-At-Once has created a graphical front-end for CDRDAO which is free for non-commercial use. CDBurnerXP Pro is a decent <i>freeware</i> CD burner for Windows, although it is not <i>free software</i> . Annoyingly, it defaults to ISO 1, so you have to select ISO 2 if you don't want shortened filenames. In GNU/Linux, K3B is an excellent CD/DVD burner, but it hasn't been ported to Windows.	Command Line: Win, Linux, Mac

<i>Software Category</i>	<i>Proprietary Programs (Cost in US)</i>	<i>FLOSS Alternative</i>	<i>Comparison</i>	<i>Platforms</i>
First-person shooter game	ID Software Doom (\$20, \$25) & Quake (\$40, \$50) 3D Realms Duke Nukem (\$19.99)	Cube	Cube doesn't have any artificial intelligence, so you can only play against other human beings in internet multi-person play, but the graphics engine is rather nice.	Win
War Strategy Game	Blizzard Warcraft (\$19.99, \$29.99) MS Age of Empires (\$49.95)	Wesnoth	Not as slick as some of the commercial games, but definitely an enjoyable battlefield strategy game.	Win
Personal Database	MS Access (\$229, in MS Office Pro: \$499) Corel Paradox (in WP Office Pro: \$399) MS Visual FoxPro (\$649, in Visual Studio: \$299, \$799) FileMaker Pro (\$299, \$499)	OpenOffice.org Base	OOo Base is currently only a limited replacement for a visual database like Access, but it is rapidly improving. Although there are a number of excellent free software databases, none have as good of a GUI interface as the proprietary databases. There is certainly no visual programming database program like Visual FoxPro in free software.	Win, Linux, Mac
Enterprise Database (Server)	MS SQL Server (\$3899, \$5999, \$24999) Oracle Database (\$400, \$4995, \$40000) IBM DB2 SAP	MySQL	MySQL is a small and quick database that outperforms most propriety databases in small and medium scale server applications. Before version 5 it didn't support many of the functions used by large enterprise databases.	Win, Linux, Mac
		PostgreSQL	According to test data, PostgreSQL is faster than Oracle. It supports all the advanced database functions and is an excellent large-scale enterprise database.	Win, Linux, Mac
Web Page Server	MS Internet Information Server (in Windows XP Pro: \$299, in Windows Server: \$999, \$2999)	Apache	Apache is faster, more secure, and has more configuration options than IIS. Roughly 70% of webpage servers use Apache.	Win, Linux, Mac
Email Server	Magic WinMail Server (\$129 - \$1299) Merak Mail Server Engine (\$264 - \$980)	Sendmail	Sendmail is more configurable and is faster than its proprietary competitors. Sendmail was one of the first email serving programs and is used by over 40% of email servers, making it the market leader. If looking for a highly secure email server, check out postfix for UNIX-like systems.	Win, Linux
C/C++ Programming	MS Visual C/C++ (in Visual Studio: \$299, \$799) Borland C++Builder (\$1090, \$2490, Turbo: \$399) Freescale CodeWarrior	Bloodshed Dev-C++	Bloodshed Dev C/C++ is an integrated development environment (IDE) like Visual C/C++ in Visual Studio. It uses the MinGW (or alternatively Cygwin compiler which is based upon the gcc (GNU compiler collection)). Bloodshed can only compile C/C++ code, but in GNU/Linux there are nice multilingual IDEs like KDE Developer and Anjuta DevStudio which are comparable to MS Visual Studio. For cross-platform programs, write C/C++ programs using free libraries like GTK+ and wxWidgets which will run in almost any operating system.	Win
		MGWin Developer Studio	MGWin Developer Studio is an IDE for the MinGW compiler. It comes with a nice resource editor for creating visual components for your programs.	Win, Linux
C# Programming	MS C# (in Visual Studio: \$299, \$799, \$2499) Borland C#Builder (\$1090, \$2490, \$3490, Turbo: \$399)	Mono	Mono is a free software implementation of C# that runs in both Windows and Unix-like systems. It hasn't implemented all of the MS C# libraries yet and doesn't come in an IDE like Visual Studio.	Win, Linux, Mac
Pascal Programming	Borland Delphi (\$1090, \$2490, \$3490, Turbo: \$399)	Bloodshed Dev-Pascal	Bloodshed Dev-Pascal is an IDE which can use either the Free Pascal or GNU Pascal compilers. Although it doesn't have the Rapid Application Development and other visual	Win

<i>Software Category</i>	<i>Proprietary Programs (Cost in US)</i>	<i>FLOSS Alternative</i>	<i>Comparison</i>	<i>Platforms</i>
			programming features of Delphi, it is a good tool for teaching programming.	
BASIC Programming	MS Visual Basic (in Visual Studio: \$299, \$799, \$2499)	GNU/Liberty Basic Compiler Collection (GLBCC)	There are a number of free Basic interpreters/ compilers available. Probably the best for general use is the GLBCC, although it doesn't come with an IDE. The next version of wxBasic for wxWidgets programming looks promising, although the current version is incomplete and difficult to use. Mono's Basic.NET Compiler also bears watching for people who program in MS Visual Basic, although it is currently not a complete implementation .	Win, Linux
Java Programming	MS Visual J++ (in Visual Studio: \$299, \$799, \$2499) SUN Java (\$0) Borland JBuilder (\$499, \$3500, Turbo: \$399)	GCJ (GNU Compiler for Java) + ClassPath	Although programmers can develop Java programs without paying licensing fees, SUN has been roundly criticized for not releasing Java as free software. It appears that SUN will give Java a free software license in the future, but in the meantime, the GNU Compiler for Java (GCJ) and Classpath can replace SUN's Java. Unfortunately, Classpath hasn't implemented all of SUN's java libraries yet, so some Java code won't run with it. For a good development environment for Java, check out Eclipse .	Win, Linux, Mac
		Eclipse	Eclipse is an IDE and toolkit for 12 different languages, including C/C++, Fortran, PHP, Perl, Python, and Ruby, but it most used for Java programming. The Eclipse SDK uses a different widget toolkit than standard SUN Java and has a number of GUI tools to simplify the construction of applications.	Win, Linux, Mac
Compression	Corel WinZIP (\$29.95 - \$59.90) RARLAB WinRAR (\$29) PKWARE PK-ZIP (\$29) WinAce (\$29, \$39)	7-Zip	7-Zip can decompress 15 different compression formats, so it can open just about any compressed file. It has a unique compression format which is 10% more compact than RAR and 75% more compact than the standard ZIP compression used by most programs. It's only drawbacks are its odd interface and the fact that it can't decompress multi-volume ZIP files.	Win, (Command Line: Linux, Mac)
Anti-virus	Symantec Norton AntiVirus (\$39.99) McAfee AntiVirus Plus (\$39.99)	ClamWin Free Antivirus	ClamWin is based on the ClamAV scanning engine which has a relatively high rate of virus detection. ClamWin does not an on-access real-time scanner like some of the proprietary anti-virus programs, but it does have a scheduler for regular anti-virus scanning and a plugin to scan email in MS Outlook for viruses.	Win
Internet Security (anti-spyware, etc.)	McAfee Internet Security Suite (\$49.99) Symantec Norton Internet Security (\$69.99)	<i>currently none</i>	Since most forms of internet malware simply don't function in GNU/Linux, few free software developers feel the need to develop counter-measures for a threat that doesn't bother them. If you need freeware to protect against spyware, try LavaSoft's Ad-Aware SE Personal .	
Network Security Scanner	Tenable Network Security Nessus (version 3) (\$1200 per year)	nmap	nmap scans networks for security problems. In Linux, nmap can be used with the GUI front end nmapFE, but in Windows it can only be used from the command line.	Win, Linux, Mac
		Nessus (version 2) / OpenVAS	Nessus is an excellent network security scanner which used to be free software, but Tenable Network Security decided to turn it into proprietary software with version 3. Open source advocates are developing a free version called OpenVAS based upon the old version 2 code, but it is not yet available for download.	Win, Linux

<i>Software Category</i>	<i>Proprietary Programs (Cost in US)</i>	<i>FLOSS Alternative</i>	<i>Comparison</i>	<i>Platforms</i>
Scanner and OCR (Optical character recognition)	Nuance OmniPage (\$149.99, \$499.99) ABBYY FineReader (\$199, \$399) NewSoft Presto! (\$99.95)	GOCR	There is no free software in Windows for controlling scanners. For OCR, GOCR is a very rudimentary command-line tool for converting image files into text files. Nobody has created a graphical interface for it and people who aren't used to the command-line will find it difficult to use. If you want the help files, you have to download the source files as well.	Win
Voice Recognition	Nuance Dragon NaturallySpeaking (\$99, \$199, \$899) IBM ViaVoice (\$29.99, \$49.99, \$79.99, \$189.99)	<i>currently none</i>	None of the current free software voice recognition projects are developed to the point that they can be used by normal Windows users. IBM recently released some key code as free software, so we may see something in the distant future.	
Command Line	MS-DOS (in Windows XP: \$199, \$299)	Cygwin	DOS is extremely limited as a command line interface, which should be avoided when possible. Cygwin is a UNIX emulator which provides the basic command line capabilities of UNIX inside Windows. Cygwin can be used to manipulate Windows files, but can't run BAT files or Windows programs, so it can't fully replace DOS in Windows.	Win
		FreeDOS	FreeDOS is a free software implementation MS-DOS. It works fine as a DOS boot disk, but it won't run inside of Windows 95 or later.	

Installation of Spanish Versions of the software

Most of these free software programs will automatically detect the default language in Windows and set it as the user interface language. Some programs however require special downloads or the user interface language needs to be selected.

OpenOffice.org

After installing the English version of OpenOffice 2, download and install the Spanish Language Pack. It should automatically put interface in Spanish, but if not, go to **Tools->Opciones->Language Configuration->Languages** and select **Español** as the **User Interface Language**.

To add Spanish spell-checking, go to **Archivo->Asistentes->Instalar diccionarios nuevos**. Select **Español** and click **Ejecutar DicOOo**. After downloading the Spanish [es_ES] dictionaries for spelling, silable separation, and synonyms, exit and restart OpenOffice. If you have set up OpenOffice for quickstart, you will have to exit that as well. Look for the OpenOffice icon in the expandable tray on the right-hand side of the taskbar in Windows and right-click on it. Select the option **Salir de Quickstarter**. After restarting OpenOffice, go to **Herramientas-> Opciones-> Configuración de idioma-> Lingüística**. Under **Modulos disponibles de idioma**, click **Editar**. In the **Editar Modulos** dialog box, select **Español (España)** under **Idioma**.

To spell check in Spanish, select the text, then go to **Formato->Carácter** and select **Español (España)** under **Idioma**. To set Spanish as the default language for spell checking, go to: **Herramientas-> Opciones-> Configuración de idioma-> Idiomas**. Bajo **Idiomas predeterminados para los documentos**, select **Español (España)** for **Occidental**.

If Espanol does have check mark next to it when selecting it from the list of language, then OpenOffice can't find the dictionary files for Spanish. Exit OpenOffice, and go to the **C:\Program Files\OpenOffice.org 2.0\share\dict\ooo** directory and make sure that you see the files **es_ES.dic**, **es_ES.aff**, **hyph_es_ES.dic**, **th_es_ES.dic**, **th_es_ES.aff**. If not, you will have to download these files and

place them in the directory. Then add the following lines to the **dictionary.lst** file in the same directory:

```
DICT es ES es_ES
HYPH es ES es_ES
THES es ES es_ES
```

Save the file as bare text and then restart OpenOffice. Now it should be able to spell-check in Spanish.

If you want to set your documents to spell check in Spanish from another country, you will have to rename your dictionary files to the ISO code for that country. For instance, if you want to set Peruvian Spanish as your language, you will have to rename the dictionary files to **es_PE.dic**, **es_PE.aff**, **hyph_es_PE.dic**, **th_es_PE.dic**, **th_es_PE.aff** and change the **dictionary.lst** file to:

```
DICT es PE es_PE
HYPH es PE es_PE
THES es PE es_PE
```

Mozilla-based Software

[NAVE](#) offers full Spanish versions of Mozilla Firefox, Thunderbird, Sunbird, SeaMonkey, and Nvu for download. Or you can install the English version and then later install a separate XPI Spanish Language Pack.

Mozilla Firefox

After installing the XPI Spanish Language pack, go to: **Tools-> Options-> Advanced-> General**. Click "**Edit Languages**" and in the "**Languages**" dialog box, click "**Add**" and select "**Spanish [es]**" from the list. Then click on "**Move up**" to put Spanish first on the list.

Seamonkey

To install the XPI Spanish Language Pack go to **Edit-> Preferences-> Appearance->**

Language/Content. Click "**Download more...**" and select **Spanish**. After downloading, select Spanish as your preferred language, click "**OK**" and then restart SeaMonkey.

7-Zip

Currently there is no spanish translation of the latest version of 7-Zip, but older versions have been translated. See <http://www.7-zip.org/es> for the latest available version.

MusikCube

Currently there is no Spanish version of MusikCube, although somebody has started a translation.

MGWin Developer Studio

There is no Spanish translation available.

Appendix D: Multi-booting: Installing more than one OS on your computer

If you are setting up a thin client server, it is strongly recommended that you use a dedicated machine that has no other function. A dedicated machine will be much stabler. If you are using your thin client server for some other purpose, you might accidentally delete important files on the harddrive. It is especially risky to have multiple operating systems installed on your thin client server. Generally, GNU/Linux plays nicely with other operating systems, but MS Windows does not. MS Windows installers only recognize older versions of Windows. If you install or reinstall Windows, afterwards you will no longer have the option to boot into GNU/Linux or newer versions of Windows which are installed on other partitions. In addition, if you decide to add another partition to your harddrive, you can foul up your existing installations of GNU/Linux, because repartitioning will renumber all the partitions on your harddrive. Your installations of GNU/Linux might not be able to find the swap partition since it has been renumbered.

It is possible to recover from all these partition problems, but it takes some experience. If you have never dealt with multi-booting before, it is recommended that you avoid these problems by only running one operating system on your harddrive. Whatever you do, make sure that you have made backups of all your existing data and have the installation disks for all the software on your computer. You need to be prepared to reinstall everything on your computer if you are going to play with multi-booting.

Often people who are investigating the possibility of using a thin client network want to set up a test thin client server, but don't have a spare computer handy. If you want to give a thin client network a test run before investing too much money, you might think about just buying a separate harddrive, rather than trying to set up a dual boot machine on your existing computer. This way you can avoid the hassles and risks of dual booting. Take out your existing harddrive and put in your new harddrive. Then install your thin client server on your new harddrive. Once you get your thin client network working correctly, then you verify whether the thin client network will serve your needs and whether it is worth buying a whole new machine to be your thin client server.

Another option to multi-booting is to set up virtual machines with a program like Qemu, Zen, Vmware or Virtuozzo. These programs allow additional operating systems to be installed inside of an existing operating system. Setting up virtual machines is a bit tricky, but may be worth the effort if you need to be able to access multiple operating systems at the same time.

On the other hand, multi-booting can be handy in some cases, especially if you work in an environment when people run both GNU/Linux and Windows. For instance, some schools are beginning to teach classes on GNU/Linux, but still need to use Windows for their normal classes. The harddrive of each workstation can be configured to provide a menu of the available operating systems at startup, so the user can choose whether to run GNU/Linux or Windows. In some thin client networks, the user can choose to boot the workstation as a thin client, or as a fat client, depending on the type of work to be done.

If you plan on installing multiple operating systems on your computer and multi-booting,

Microsoft [recommends](#) installing the operating systems in the following order:

- MS-DOS
- Windows 3.X
- Windows 95/Windows98/Windows Me
- Windows NT
- Windows 2000
- Windows XP
- Windows Server 2003
- Windows Vista
- GNU/Linux or any other OS

Install each operating system in its own partition. Although multiple Microsoft operating systems can be installed in the same partition, errors will often occur as different operating systems look in the same location for their files.

Recovering previous installations of Windows

If you already have Windows Vista installed on your computer, it probably won't run after you install Windows Server 2003. By default, Windows rewrites the Master Boot Record (MBR) when it installs the bootloader. Since Windows doesn't recognize GNU/Linux partitions, you won't be able to boot any of your existing GNU/Linux partitions. Plan on having to reinstall Windows Vista and GNU/Linux after installing Windows Server 2003. If you install Windows 2000 Server, you will probably need to reinstall Windows XP, Windows Vista, and GNU/Linux afterwards.

You may be able to recover your previous installation of Windows XP or Vista. Insert the original Windows installation CD and reboot the computer. When starting up, you will be asked to press any key to boot from the CD. Select **R** to enter recovery mode. Windows will then check and reinstall any needed files. Since Windows is rewriting system files, you may have to uninstall, then reinstall certain programs afterwards, so they will function correctly.

Reinstalling the Master Boot Record (MBR)

If you want to recover your previous installation of Windows, without reinstalling the operating system, it may be possible to recover it by just reinstalling the Master Boot Record (MBR). The MBR is the first 512 bytes in Sector 0 of the harddrive which tells the computer where there are partitions in the harddrive and where in the harddrive to boot from.

Restoring Windows 95/98

If you have an installation of Windows 95, Windows 98, or Windows 98_SE, you can recover your installation using a Windows 98 Installation CD. Insert the CD and reboot your computer. Select support for the CD-ROM and it should boot from the Installation CD. When you see a command prompt, enter:

```
fdisk /mbr
```

This should restore your Windows installation, but it won't restore any installations of GNU/Linux

or later versions of Windows. You will have to use a Linux Installation CD to restore your GNU/Linux partitions.

Restoring Windows XP

If you have Windows XP installed on your computer, insert a Windows 98 or Windows XP Installation CD and reboot the computer. If using the Windows 98 Installation CD, use the `fdisk /mbr` command above to restore the MBR. If using the Windows XP Installation CD, press any key at the startup to boot from the Installation CD. Enter the Recovery Mode by pressing **R**. Select the drive where Windows XP is installed (which is probably the C drive). At the command prompt, enter the command:

```
fixmbr
```

When done reinstalling the MBR, then enter the command:

```
exit
```

Now the computer should be able to boot into Windows XP.

Recovering previous installations of GNU/Linux

There are several different ways to recover previous installations of GNU/Linux after installing Windows. The easiest, but least reliable method is to reinstall GNU/Linux. This is very similar to reinstalling Windows in recovery mode. Many Linux installation CDs have a recovery mode which will boot the computer into a command line prompt. Some Linux distributions come in the form of a Live CD, which will allow you to boot up the computer and enter a Graphical User Interface (GUI). You will be able to open a terminal window to use the command prompt.

From there you should be able to recreate the master boot record (MBR). Today most distributions of GNU/Linux use the GRUB boot loader, which has a special program to restore your MBR so you can multi-boot. A few GNU/Linux distributions like Mandriva still use the antiquated **lilo** boot loader. For recovering Mandriva, Fedora, or SuSE read [these instructions](#). For Ubuntu read [these instructions](#).

The following are general instructions which ought to work for most GNU/Linux distributions which use the GRUB boot loader.

Insert a GNU/Linux installation CD and reboot the computer, then select the option to enter the command line or recovery mode. If using a Live CD, wait until the computer boots up in graphical mode, then open a terminal window. Once you see a command line prompt, switch to the root user:

```
su    (in distributions based upon Ubuntu use: sudo -i)  
        Enter the root password and press return.
```

Now enter the **grub** program:

```
grub
```

When inside the grub shell prompt "`grub>` ", find your previous installations of GNU/Linux:

```
find /boot/grub/stage1
```

This command should return a list of all the installations of GNU/Linux on your computer which

use the GRUB boot loader. (It won't find distributions of GNU/Linux which use the **lilo** boot loader.) Whatever is returned, use in the next command. If you have multiple installations of GNU/Linux, select one of them. Tell GRUB which partition to boot from:

```
root (hd?,?)
```

For instance, if the find command returned (hd0,1), then you would enter **root (hd0,1)**.

Next, enter the command to rewrite the MBR so it points to the partition indicated by the **root** command:

```
setup (hd0)
```

The MBR should now be reinstalled. Finally, exit the grub shell:

```
quit
```

When the computer is rebooted, it should be able to boot to GNU/Linux. If you have both Windows and GNU/Linux installed on the same machine, you may need to add Windows to the list of operating systems which the machine can boot. To do this, boot into GNU/Linux, then open a terminal window. Use your favorite text editor to edit the file **/boot/grub/menu.lst**. If you need a simple text editor, which works inside a terminal window, try the **nano** editor:

```
nano /boot/grub/menu.lst
```

Text which follows the # (number sign) is a comment and will be ignored by the computer. You will now need to add Windows to the list of operating systems that can be booted. For instance, here is an example of a menu.lst file for a computer which has Windows XP Professional in the first partition (hd0,0) and Edubuntu 6.10 installed in the second partition (hd0,1):

```
title      Windows Server XP Professional
root       (hd0,0)
savedefault
makeactive
chainloader+1

title      Edubuntu, kernel 2.6.17-10-386
root       (hd0,1)
kernel     /boot/vmlinuz-2.6.17-10-386 root=/dev/hda3 ro quiet splash
initrd     /boot/initrd.img-2.6.17-10-386
boot
```

When done editing menu.lst, exit and save the file. In **nano**, you can exit and save by pressing **Ctrl X**. You will be asked if you want to save the file. Press **Y** to answer “yes”, then press **Enter** to save it under the same name. The next time you reboot, you should see a menu of operating systems and be able to select the operating system which you want.