

Thin Clients and Computers' Recycling

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Abstract. This document shows the achieved results in the installation and testing of thin clients' networks (TCN), arranged with obsolete computers. This research topic arises from previous investigations and it is framed in a wider project which includes the use and compatibility of free and/or open source software (FLOSS¹). In this paper, details of how the network was implemented are given; a list of specifications with minimal parameters for a suitable use in classroom is proposed; actions which improve the operation and some of the achieved results in the evaluation of the network are showed as well.

Keywords: thin client, Ubuntu, open source, free software

1. Introduction

We wanted to analyze the performance of a set of software, mainly educational ones, on a TCN, supported by a Linux Distribution. Our interest in the thin clients comes from the possibility that this kind of arrangement could bring to educational institutions with limited resources in terms of computer equipment. Particularly, in those which have not been included in the "Conectar igualdad"² project.

"Thin client is a generic term describing a group of rising technologies which reduce hardware maintenance and costs of support; at the same time they also save bandwidth, reduce collapse time and improve network security" [4]. A TCN implements a scheme where most part of processing, or the whole of it, is realized in the server and not in client machines. Applications stay at the server, they are processed in it, and their results are observed in client machine [14]. The "thin" term derives from the scarce processing taking place in the client, as opposite to the term "fat" client, used when the client is responsible of most of the processing.

¹ FLOSS: free/libre/ open-source software. For further information, see: <http://twit.tv/FLOSS>.

² The "Conectar Igualdad" project, of Argentinean Government, intents to implement the OLPC (One Laptop Per Child) concept. Further information in: (<http://www.conectarigualdad.gob.ar/>).

In a TCN, applications and documents are stored at the server, which is in charge of processing clients' requests and managing their sessions and all the applications installed in the server will be available for the clients. Requirements of hardware are directly proportional to the number of connected clients. That is to say, requirements increase at the same time as the amount of stations increases.

A TCN typically consists of:

- One or more servers.
- A group of thin clients.
- An operating system supporting a thin client's model.

Our TCN implementation follows other experiences like this of New Technologies Research Laboratories in La Plata, Argentina [12], Telesecundaria School of San Baltazar Guelavila in México [15] and Risaralda Department in Colombia [20].

Although the main attraction of a TCN is the possibility of recycling obsolete machines (which is a very important cause in the continuous increasing number of world wide TCN³). Some extra benefits of TCN are:

- *Minimal hardware requirements.* From the hardware point of view, clients have fewer components than a standard network station; for example, if they boot from a diskette, there is no need for stations to have hard disk or CD-ROM. If clients boot from a network card including boot ROM⁴, diskette driver is not needed.
- *Minimal network traffic.* Network traffic keeps slow, because the only flow of data which is transmitted in it is reduced to client's input/output, basically: keyboard, mouse and video.
- *Hardware changes are limited to improvements in the server or in the network.* Increasing the amount of RAM memory, placing a quicker hard disk, changing the switch for a more efficient one, placing several network cards in bonding⁵ or having more than a server, will generate a better integral performance of the system. Hardware costs are drastically reduced. Improving the performance of clients in a distributed configuration implies investment in optimization in each station.
- *A mixed implementation is possible.* This is, connection among computers which are in the same room must be wired, but from the server to each room, a wireless connection may be used (see Fig. 1).
- *Centralized installation.* From the software point of view, installations take place only in the server, avoiding duplication of efforts in each station.
- *Centralized backup.* Clients' files are kept in the server, permitting a centralized backup. This issue, crucial in any context, is especially important for teaching activities, because allows the recollection of students' production using a removable storage device. In a distributed system, those documents are stored in each station.

³ Ncomputing enterprise has set up 2.000.000 thin workstations in 100.000 enterprises. For further information see: http://www.frm.utn.edu.ar/alumnosis/index.php?option=com_content&view=article&id=62:thin-client&catid=3:newsflash&Itemid=37.

⁴ A memory chip which lets workstation boots from a server or other remote station.

⁵ Channel bonding or Ethernet bonding consists of simulating a larger bandwidth joining several independent network cards that applications will see as one.

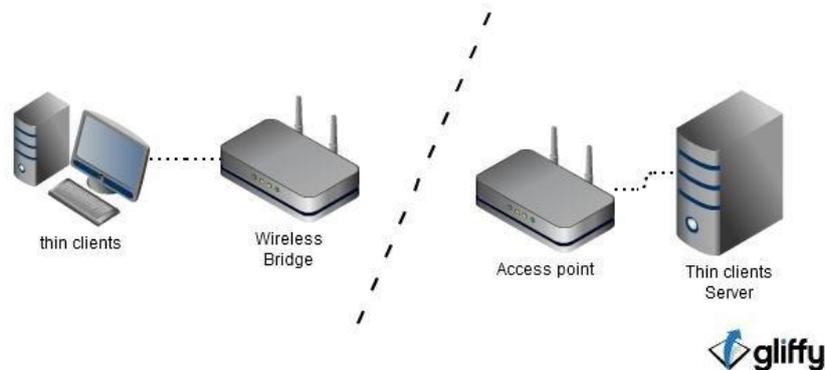


Fig. 1. Scheme of a TCN implemented in a mix form.

- *Versions of software and operating systems are unified.* Frequently, computers of a network are gradually replaced. As a consequence of this, it is common that a network includes equipments with different versions of the operating system (Windows 95, 98, 2000, XP, Vista, 7, different Linux distributions) and this produces a lack of uniformity on the set of applications that each of them may carry out. This could be a serious problem in an educational institution, since it makes the operation of the equipment complicated, adding difficulties to teaching, due to the conflict among different system operating versions and file formats, especially for teachers with little computer literacy.
- *It is possible to watch the students working.* Teachers have access to their student's workstations; thus, the teacher may make comments about what each student is doing. ITALC⁶, is an application which let teachers watch on their screen, the tasks that students are fulfilling and, also from their computers, they may participate in the process, making corrections, suggestions and comments, and operate in each student's station, too.
- *Environmental impact.* Thin clients approach, makes an important contribution to reduce the level of electronic waste. In fact, computer industry generates a great amount of e-waste, principally because, in many cases, these are neither manipulated properly nor by people specialized on the subject⁷.
- *This model is especially intended to reduce the effects of the "digital divide"*⁸. This is recycling of obsolete computing technology could give more people access to technology. When companies upgrade their computers, they usually discard and convert the old equipment in e-waste. It could be recycled.

⁶ ITALC: Intelligent Teaching And Learning with Computers, Further information available at: <http://jaimebalmes.edu.gva.es/mod/resource/view.php?id=570>.

⁷ For further information, see: <http://www.cleanup.org.au/au/LivingGreener/e-waste.html>.

⁸ The concept "digital divide" refers to social and economic differences between those communities with access to technology and those without it [22].

2. Software for Thin Clients' Network

Regarding the software needed to implement a TCN, there are many possibilities. FCEyN network uses Ubuntu as server's operating system with LTSP⁹. This Linux distribution offers a great amount of applications (especially educational ones, for instance, Edubuntu¹⁰) and due to the popularity¹¹ of this software is foreseen that the number of applications will keep growing. Ubuntu versions used in this project, 9.10 and 10.04, include an installation of server, using Alternate distribution.

The chosen thin clients' manager is LTSP. Other products, such as Tcos and Thinstation were analyzed. Even though each of them has its own advantages, LTSP was chosen because of its strong connection with Ubuntu. Description of different patterns of thin clients' managers goes beyond the limits of this paper; however, references about them are included in the last section of this paper.

A thin clients' network requires:

- DHCP (Dynamic Host Configuration Protocol). It is used to assign IP temporal addresses automatically to clients.
- FTP (File Transfer Protocol. Internet protocol). It allows a computer to send or receive files from another computer. Trivial File Transfer Protocol is necessary [2]. It is a simpler version of FTP protocol, which is used to transfer small files among network stations. TFTP is frequently used to transfer firmware updates to routers and switches.
- NFS (Network File System): it is used to mount the client's file system in the hard disk of the server.
- XDMCP(X Display Manager Control Protocol): it is used to execute graphical environments through the network.

Alternate installation provides an easy way to implement all the needed configuration, producing changes in several files, which are described below, also showing the way in which these changes could be done manually.

- *DHCP server installation and configuration.*

Automatic installation of Ubuntu Alternate, includes DHCPD3 server. Manual installation may be carried out from the terminal console using:

```
$apt-get install dhcp3-server
```

And, to start service (as root user):

```
$service dhcp3-server start
```

In our case, all services were configured to start at server's boot.

There are two configuration files that have been modified during installation:

⁹ LTSP: Linux Terminal Server Project. For further information see: <http://www.ltsp.org/>.

¹⁰ The Edubuntu Project: Edubuntu is a grassroots movement, which aim to get Ubuntu into schools, homes and communities and make it easy for users to install and maintain their systems. For further information see: <http://www.edubuntu.org/>.

¹¹ According to DistroWatch.Com (<http://distrowatch.com/index.php?language=ES>) and DesarrolloWeb.com (http://www.desarrolloweb.com/de_interes/ranking-distribuciones-linux-febrero-2010-3061.html), Ubuntu is the most popular Linux distribution since February, 2010.

- `/etc/dhcp3/dhcp.conf`: in this file, characteristics such as exact range of IP addresses of the network, submask, IP address assigned to server network card which will provide the clients with DHCP, and root path which the clients will look for, are specified.
- `/etc/default/dhcp3-server`: In this file, it is essential to indicate which of the network cards available in the server will be in charge of providing DHCP, through a line as the following:

```
INTERFACES=eth1
```

b. FTP server installation and configuration.

To send boot images to a thin client, the protocol TFTP is used. If manual installation, the next command must be used:

```
$sudo apt-get install tftp
```

After installation, to start service:

```
$sudo service tftp -hpa
```

c. LTSP Environment Building.

The next commands must be used:

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

```
$ltsp -build-client
```

The default generated image will be given by the processor architecture. If we want to create an image of 32 bits, we must be add the `-archi386` modifier.

d. LTSP general configuration.

The LTSP configuration is included in the file `/var/lib/tftpbboot/ltsp/i386`. Such file has several options which may be modified in case that automatic configuration wouldn't work: video driver, color depth, screen resolution and refresh frequency among others¹².

Thin client boot images may be obtained from Etherboot Project¹³. PXE¹⁴ protocol is used by clients for remote boot. It provides a common and consistent set of pre-boot services and a uniform protocol for the client to request the allocation of a network address [1][10].

e. Steps after installation:

- Install backup utility: this is essential for system operation. Remastersys¹⁵ was used. It is an utility to create an ISO image of the system. To reduce the amount of data to save, localepurge¹⁶ could be used previously.

¹² For further information, see: <http://groosd.blogspot.com/2011/04/example-ltscnf-file-for-ubuntu-1004.html>.

¹³ For further information see: <http://www.rom-o-matic.net/>.

¹⁴ PXE (Preboot eXecution Environment): is an environment to boot computers using a network interface independently of data storage devices (like hard disks) or installed operating systems.

¹⁵ Available at: <http://www.geekconnection.org/remastersys/ubuntu.html>.

- In many cases, recycled computers do not allow a mouse other than serials. For the thin client to support these, we must edit the server file:

```
/opt/ltsp/i386/usr/share/ltsp/ltsp-init-common
```

We change the line:

```
inputattach --"$X_MOUSE_PROTOCOL" "$X_MOUSE_DEVICE" &
adding, the setsid word, at the beginning.
```

- It is possible to select the desktop theme in the clients, using the next commands:

```
sudo chroot /opt/ltsp/i386 update-alternatives --config
ldm-theme

sudo ltsp-update-image
```

3. Network implementation

Among the most interesting features in TCN is the possibility of recycling obsolete computers, making their life-cycle longer. FCEyN network was built with components which were meant to be discharged. Those computers (see Table 1), which were not considered capable of offering any more useful services, have been rescued and put to work again in an acceptable way and at a very low cost.

Table 1. Thin clients hardware in FCEyN network.

<i>Client 1</i>	Celeron I 333 mhz, 128 mb RAM
<i>Client 2</i>	Pentium III 450 mhz, 128 mb RAM
<i>Client 3</i>	Pentium III 450 mhz, 128 mb RAM
<i>Client 4</i>	Athlon XP 2400mhz, 128 mb RAM

We Decided that all the clients would have the same amount of RAM memory (128 mb), since in every test we have taken it was possible to probe that stations are not capable of playing multimedia material if they don't have at least 96 mb. If the system were only assigned to office applications, the computers with 64 mb RAM would have a satisfactory behavior [11], but for educational workstations, multimedia should be considered essential.

All the computers connected to the FCEyN have hard disks between 2 and 6 gb. However, these disks only include a Grub¹⁷, related to TCN and the remaining space stores some version of local Linux. For instance, "Linux Introduction" course uses

¹⁶ This application may be installed from Synaptic Packets administrator. Further information in: <http://www.guia-ubuntu.org/index.php?title=Localepurge>.

¹⁷ GNU GRUB (Grand Unified Bootloader) is a multiple boot manager, developed by the GNU project, and it is commonly used to select one of two or more operating systems installed in the same computer.

those disks to install and teach the use of other Linux distributions. Today, the FCEyN network has two servers with the characteristics shown in Table 2.

Table 2. Characteristics of thin clients' servers.

<i>Server 1</i>	Amd Athlon 64 X2 model 4200+, hard disk 160 gb SATA II, hard disk 30 gb IDE (to SWAP and common data) and 2 gb of RAM memory DDR2 667 mhz, in Dual Channel mode. Ubuntu 9.10 installed.
<i>Server 2</i> (portable server)	Notebook DELL LATITUDE E5500. Processor: Intel Core2 Duo T7250. 2 gb of RAM memory DDR2 and a hard disk of 160 gb sata. Ubuntu 10.04 installed.

To test the performance of the network, an Mpeg video of 640 x 480 pixels and DivX codification was used (Fig. 2). Initially, its performance was observed without monitoring tools. Later, system monitor was opened to record the resources' use (memory, CPU and network traffic). The test was carried out using the clients (see Table 1) in two different servers (see Table 2). To test CPU use, HTOP¹⁸ application was used, BWM-NG¹⁹ was deployed to test network's traffic, and also system monitor was used.

- *Server 1 (see Table 2):*

Video sound is perfectly played in the four clients at the same time. Video reproduction shows small delays.

When opening the system monitor, it was observed that videos continue playing without changes. Resources behavior is shown in Table 3.

Table 3. Resources' use when four videos are playing.

CPU	90.00%
RAM memory	500 mb
Network Traffic	50 mbps

At the end of the four videos, CPU use decreases to 35%, memory use does not show changes and network traffic does not show activity.

When stopping the first client, it was verified: CPU use was at the same range, traffic decreased to 30 Mbps and memory use lowered to 440 mb.

When stopping the second client, memory use remains at 440 mb, network traffic and CPU remain without changes.

When stopping the third client and closing video applications of inactive clients' memory, use lowered (350 mb) but network traffic and CPU use maintain without modifications.

During the test, clients show important delays to answer local events. These results seem to indicate that the system compensates local performances

¹⁸ HTOP is an interactive process viewer for Linux. Available at: <http://htop.sourceforge.net/>.

¹⁹ BWM-NG: Bandwidth Monitor NG is a small and console based live network and disk I/O bandwidth monitor. Available at: <http://sourceforge.net/projects/bwmng/>.

according to requirements, improving the local videos when the number of clients working decreases. It is important to highlight that memory use is slightly modified when clients are using the same application; it is due to the fact that memory in user sessions is shared, and libraries and programs are loaded once.

- *Server 2: (see Table 2)*

With four clients playing video, the reproduction is better, disappearing the stops between frames, which were seen when using server 1, less powerful. In one of the clients, the video is not shown, though the sound could be listened perfectly. This may be due to some incompatibility of this video card and Ubuntu 10.04. Resources use level is similar to the ones observed when the server 1 was tested, but the delays to answer local events disappear.

When the video in the first client finishes, monitor of the system shows the following values: CPU (nucleus 1) 35%, (nucleus 2) 40%, memory use 1 gb and network traffic, 70 mbps.

When the video in the second client ends, reading values slightly change. When the third client stops, network traffic lowers to 40 mbps, and nuclei show 25% both of them, keeping the memory use in the same level.

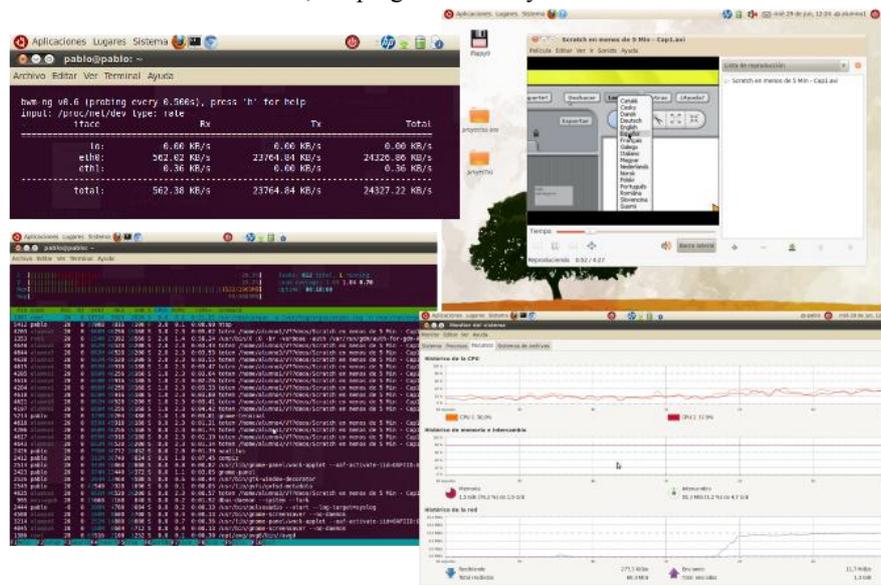


Fig. 2. The image shows the video playing and the test done with BWM-NG, HTOP and System monitor.

4. Results

The TCN installed in FCEyN, previously described, is working since February, 2010. At this moment, it is being used by the following user groups:

- Students of the optional course “Linux introduction” enrolled in “teacher in informatics” career. In these stations, students fulfill all their practical work in a Linux system, including configuration and practice related to the Ubuntu environment and the use of applications like Open Office. Network performance is enough to develop these activities. In the same way, students participated in the network setting, not only in hardware configuration but also in software testing.
- Students of the course “Programming languages” enrolled in the fourth year of the same career. They use many applications and tools such as PHP, Mysql, Eclipse, Apache, which are installed in the server and they are used directly from the thin clients. Up to the moment, network performance allows the normal work-flow of class activities.
- Researchers of this work project. Testing activities about educational application are performed.

A TCN was also installed in a High School in Macachín (a small town in La Pampa, Argentina) in May, 2011. The used server is a computer which is used to administrative tasks when there are not students at school. In it, a partition disk was added to install an Ubuntu server and a dual boot was created. The clients are ten workstations dated between 1995 and 1999, Pentium 200 MMX to Celeron I 266MHZ, which had 32 or 64 mb RAM. Using electronic waste, RAM memory amount was increased to 96 mb, to provide multimedia. At this moment, that network is being evaluated.

Alongside, we have been doing outreach activities, (workshops, and demonstrations) in order to diffuse the experience and help educational institutions where this methodology could be useful. At this moment, we are analyzing the implementation of a TCN two other primary schools in the city.

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