

**Dvorak Technology Academy  
Thin Client Computer Lab Project**

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## **Thin Client Computer Lab Project**

### **Introduction**

Computers are an integral part of 21st century life, and as such technology education is recognized as part of the Illinois Learning Standards (ISBE, 2008). A computer lab is an efficient way to deliver access to computers and the Internet to students. Traditional labs, like the one at Dvorak Technology Academy, are populated with complete, standalone computer systems. In network terms these are "fat clients", because each workstation is a complete system, with its own memory and disk space and performing most if not all computing on the local workstation. "Thin client" systems shift most of the computing, memory and storage tasks to a centralized server. The client only handles user input, like typing or mouse movement, and displaying the results of user activity. As a result, in a thin client environment, the hardware on the workstation needs only minimal functionality to run the latest software and perform current computer tasks because the actual processing is handled by a server. The life of older equipment that can no longer run the latest software is thereby extended, and maintenance tasks are simplified as most maintenance only needs to be done on the server. The thin client server needs to be robust and powerful, but this extra power is much cheaper to concentrate in one server than in multiple workstations.

This project describes an overhaul of the existing Dvorak Technology Academy PC Computer Lab to extend the life of current school resources and upgrade the lab at a minimal cost to handle current and future software functionality by changing the architecture of the lab from its current "fat client" setup to a thin client architecture. This document describes the necessary hardware, software and network structure for such lab within the CPS computing environment, as well as the proposed budget, administration, security, training and rationale for such a project.

### **Project need**

In a lab setting, each student has access to a workstation, and a technology teacher can provide instruction to many students at once. In addition, students can use the lab for self-directed projects. The concentration of machines in one location simplifies maintenance. However, the Dvorak PC computer lab is designed around standalone personal computer systems, where each workstation includes a CPU with a local hard drive and operating system. This "fat client" setup ("fat" because each workstation is a

complete computing system) means that software updates and disk maintenance must be done on each system (in this case, 32 machines). Such fat clients are also relatively expensive to set up and upgrade, because each machine requires its own memory, disk space, operating system and installed software.

Dvorak Technology Academy currently has an aging set of computers in its PC lab. Of the 32 systems, approximately half were purchased during the Windows 98 period, with only 128mb of memory. As a result, they are unable to take advantage of advances in Microsoft software, including features in Windows XP, web applications and Office software. If the machines can run the software, the applications run slowly on the older processors. At the same time, the CPUs, monitors, keyboards and mice are still functional. As standalone computers they have limited functionality. They can, however, function adequately as terminals on a thin-client system. In addition, the thin client solution proposed here will also support Power PC based Macintoshes, so machines currently in storage and awaiting disposal can also be pressed into service if needed.

Dvorak Technology Academy, like most Chicago Public Schools, is faced with chronic budget problems which make it difficult to continually maintain up-to-date computer systems that provide student and faculty access to the latest developments in software and Internet technology. A thin client lab will allow Dvorak to extend its financial resources by saving on new computer resources and extending the life of existing assets.

In addition, computer lab fat clients require substantial maintenance to keep the systems in working order. While CPS's computer support systems help with this task through programs like Deep Freeze, routine hardware maintenance as well as software installs and updates not covered by CPS can be a significant drain on technology coordinator resources. A thin client architecture can reduce the workload of the technology coordinators by centralizing management and reducing the kinds of workstation maintenance that needs to be done.

Finally, thin client networks are very scaleable. If, in the future, web-based applications or productivity applications require more processing power than is currently available in the lab, additional servers can be added to the system to handle the added load instead of upgrading all of the workstations. As classroom desktop computers are upgraded, the older classroom machines can be used as additional workstations in the lab, or replace failing lab systems, or deployed in a new lab.

## **Project description**

The Thin-Client Computer Lab Project creates a computer laboratory built around thin-client

computing using open source software as an extension to a Chicago Public Schools (CPS) network. It will re-purpose existing equipment that is no longer capable of running the currently supported OS (Windows XP or Vista).

The Edubuntu Project (see <http://www.edubuntu.org> for more information) has worked to make Linux-based systems appropriate and available to classroom use. It is based on the Ubuntu distribution of Linux<sup>1</sup>, and is actively supported by its corporate sponsor, Canonical Ltd and an active community of Edubuntu users and administrators (Edubuntu, 2008). Users that are familiar with using graphical user interfaces (GUIs), including basic mousing and window skills, will have little or no problem adapting to the Edubuntu GUI. In addition to a complete range of standard business and personal productivity software (including OpenOffice, another open source project; similar to Office XP in its functionality; and supported by Sun Microsystems), Edubuntu also bundles a variety of educational software for all grade levels. Edubuntu by default installs the open source browser Firefox, so most web-based functionality will also be available to Edubuntu users. FirstClass can be accessed via the browser interface (<http://fc.cps.edu>).

Because Linux works like Unix, it handles memory management and multi-tasking in a very efficient manner, making it an ideal solution for thin client networks<sup>2</sup>. The Thin-Client Computer Lab Project will take advantage of this feature, and run the lab operations on two servers. When students start up the PCs in the lab, they will automatically contact the Edubuntu servers, and see the Edubuntu GUI on their screen. The fact that all of the processing is taking place on a server located in the MDF room will be transparent to the user. They will use the computer, for all practical purposes, just like they have used Windows-based PCs in the past.

The project calls for enough server capacity to adequately support 32 lab students using productivity software or doing Internet research. The lab is not intended for entertainment use or for multimedia / processor-intensive activities (the current Macintosh lab is available for the latter use), so the processing load on the recommended equipment should be easily manageable.

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- 1 Linux is an open source Unix-like operating system that now has a wide following in many sectors, including corporations, government and education. Linux is typically made available as "distributions", which bundle together a Linux kernel with open source tools, other software, and installation routines. Some distributions are supported by companies, others by a dedicated community of users. Ubuntu is a free Linux distribution sponsored by Canonical Ltd., which was founded by a South African entrepreneur. Ubuntu is distinguished by its ease of installation, and is rated as the most popular desktop Linux distribution (Wikipedia, 2008). "Ubuntu" is a Zulu word meaning "humanity to others" and reflects the spirit of open source computing (Edubuntu, 2008).
  - 2 While Microsoft has provided a "terminal server" option for running Windows in something like a thin client manner, it is resource hungry on the server side, and users are still faced with Microsoft licensing fees, so this option is not considered here.

The lab will continue to provide print services via a lab-based print server. These services can be provided by an existing PC system.

The current lab is not intended to provide disk storage space for students, and this option is not extended to the new thin client lab. Students will be encouraged to use network-based storage (e.g. First Class) or personal flash drives for saving documents.

### **Expected benefits**

This project is expected to benefit the instructional and service goals of Dvorak Technology Academy in several ways:

1. The project will expose students to other computer platforms, giving them broader experience and helping them generalize their computer skills so they are not tied to or dependent on a single computing platform (in particular, Microsoft Windows).
2. The project will make a range of open source education software, reviewed and approved by an active educator community, available to students.
3. The Thin Client Computer Lab Project will extend the life of existing computers, freeing up funds for additional classroom technology or for other school uses.
4. Since the project relies on free open source software, ongoing lab expenses will be minimized, freeing up funds for other school uses.
5. Because the thin client architecture simplifies system maintenance by concentrating it on the server, labor time will be freed for other school purposes, including instructional development and training.
6. Because the thin client architecture is inherently scaleable, it will allow Dvorak to grow its technology services at a minimal cost, thereby extending the use of technology at the school.

7. The thin client network will give students exposure to other computer architectures, broadening their technology experience.

## **Requirements**

In considering the scope of this project, the Thin Client Computer Lab Project solution will need to meet the following requirements:

1. Co-exist with CPS network
2. Provide access to standard computer applications (word processing, spreadsheet, web browser, and presentation software.
3. Run on Windows-98 class machines (486 processors, 128mb of RAM)
4. Provide acceptable performance
5. Support 32 simultaneous users
6. Provide redundancy in case of server failure
7. Provide for server security.

The following are *not* requirements for the project:

- heavy graphics or video processing (excepting viewing streaming video)
- permanent file storage for users. Users can use FirstClass or jump drives for storing data.

## **Required hardware and software**

The following section describes the required hardware, software, training and ongoing maintenance for the Thin Client Computer Lab Project.

### **Server requirements**

Memory is the single most critical factor in thin client computing (Edubuntu Documentation Project, 2006). This requirement will determine the minimum number of servers required for the lab.

The recommended memory allocation per client for Edubuntu is calculated according to the following formula:

$$256\text{mb} + (128\text{mb} * \text{users})$$

Since the project calls for a system that supports 32 simultaneous users, the total memory required for the servers is

$$256\text{mb} + (128\text{mb} * 32) = 4,352\text{mb}$$

or, rounding up, 5gb of RAM. Since the requirements call for redundancy, this memory should be spread across two servers, with a third server available for backup. Each server should have at least 2.5gb of RAM. Additional memory will be optimal. Faster CPUs, multiple core CPUs, or multiple CPUs will also help in performance. The following server specifications are based on the experience of Edubuntu users who have set up thin client networks. To allow for expansion, we will increase the minimum memory to 4gb per server.

**Memory:** 4gb minimum.

**CPU:** The Edubuntu distribution we will use requires Intel processors. For performance, the chip should be a dual-core Intel processor running at 2.5GHz or faster.

**Disk space:** Per the requirements, the servers do not need to provide permanent storage space for users. However, the servers will require adequate space for the Edubuntu software, caching, temporary storage (e.g. for web applications), etc. 80gb of storage will be sufficient for the servers. This disk space will need to be shared with the other servers. For performance and fault tolerance, the disk architecture should support RAID 5.

**Chassis:** The servers should be rack-mountable for locating them securely in the MDF closet.

**Network interface:** Each server must have two network interfaces for isolating the Edubuntu segment from the rest of the school and CPS network. The network interface should support 1gb Ethernet for performance.

**Software:** Current Edubuntu server software (currently 8.10, available at no charge and downloaded from <http://www.edubuntu.org/Download>).

## **Workstation requirements**

The following are minimal requirements for workstations. Recommended values are also included. All numbers are from the Edubuntu Documentation Project (2006).

**Memory:** 64mb (most of processing and memory usage takes place on the server, which is addressed above. Some memory is required on the workstation to run the small Linux kernel and applications that communicate with the server and handle the GUI.

**CPU:** At least 133 mHz CPU, 166mHz or higher recommended. Intel PCs or Power PC Macs are acceptable.

**Disk space:** Not applicable.

**Network interface:** Ethernet interface. 10mb is acceptable, 100mb is recommended. The network card should support booting over the network (using the PXE boot loader). This can be worked around.

**Graphics:** A VGA video card that uses the PCI bus and has 2 MB or more of memory, capable of 800x600 resolution.

## **Other equipment**

Because the servers will aggregate Internet traffic generated by 32 users, the servers must have adequate bandwidth to handle simultaneous requests that might include multimedia downloads viewable in a web browser. Two 1gb Ethernet switches are needed in the lab to provide connections for the workstations to the servers. The servers in the MDF room will also connect to a 1gb switch to communicate with the lab switches.

It is essential that the lab segment be isolated from the rest of the school network. This is because the lab machines need to query a DHCP server that can both assign an IP address and deliver a PXE boot file for the workstations to use. In order to shift DHCP control to technology coordinators at



Dvorak, the servers will provide DHCP services on their private network interface. The lab computers should only see the Dvorak Edubuntu DHCP servers, and obtain their public reserved IP addresses (currently planned to be in the 192.168.1.20 - 192.168.1.200 range, with a netmask of 255.255.255.0). Other machines at Dvorak should be unaware of the lab side of the network.

Two 1gb 24-port switches for the lab and one 1gb 8-port switch for the servers in MDF room should provide sufficient bandwidth to handle the lab load.

Since the computer lab is already wired, only minimal cabling for the MDF room for the new servers is required.

See "Network Diagram" below for more information on the project network topology.

### **Project organization and administration**

The project will be implemented in six phases:

Phase I: Request for proposals

Phase II: Selection of vendor(s) and acquisition of hardware

Phase III: Installation and setup of hardware and server software

Phase IV: Client testing

Phase V: Lab deployment

Phase VI: Evaluation

The project will be administered by the Technology Coordinators for Dvorak Academy. Once the lab is set up and testing is complete, the day-to-day operation of the lab will be overseen by the technology teachers. Equipment maintenance will continue to be handled by the Technology Coordinators.

### **Hardware and software security**

**Physical security:** Physical security is the protection from loss of the hardware due to theft or environmental damage. The servers will be physically secured as rack-mounted devices in the school's MDF closet, an air-conditioned, locked space. The MDF room is only accessible by the technology coordinators, custodial staff and top school administrators (principal and assistant principal). The space

meets current CPS and City of Chicago fire code.

**Operational security:** Operational security builds on physical security to ensure 100% uptime for equipment and services. Possible risks are addressed below.

**Power failure:** The servers will be connected to an Uninterruptible Power Supply (already present in the MDF room) to ensure against brief power loss or damage due to power fluctuations. In the event of a sustained power loss, power management software will initiate a server system shutdown to ensure the maintenance of the server's file system integrity.

**Disk failure:** The servers will use a RAID-5 architecture, which ensures against the failure of any single drive in the server. Data is stored redundantly across three drives, so in the event of a single disk failure, the machine can continue to operate until the failed disk can be replaced. The disk architecture includes hot-pluggable drives, allowing a drive to be swapped without shutting down the server. The budget calls for two spare drives. Additional drives can be budgeted for as necessary, but should not be required for at least three years.

**Server failure:** The project calls for three servers. Only two servers are needed for regular optimal lab performance, so the third server acts as a reserve in case of the failure of the two frontline servers. The third server will also ensure adequate performance in the event that a frontline server must be taken down for maintenance. A regular server maintenance schedule will be implemented to identify potential problems before they escalate. Automated monitoring software will be deployed to provide an early warning system of problems. Servers can be maintained from any school location.

**Network failure:** Network failure can occur for several reasons. This project makes no provision for a network failure upstream, outside of the Dvorak walls. The project budget calls for an additional 1gb switch in case one of the switches fails. While this project calls for 1gb Ethernet switches for optimal performance, the lab can continue to operate with acceptable performance using 100mb switches, using the current computer lab architecture.

**Workstations:** This project does not call for a change to physical layout of the existing PC computer lab. It also does not call for a significant equipment re-configuration of the existing lab. As a result, the security of the client workstations or the lab space is for the most part addressed by current Dvorak security precautions. PC Client workstations are secured in the current Dvorak PC Lab. The lab is locked when not in use, and accessible only by the technology teachers, custodial staff and top school administrators. Workstations are physically secured in standard computer lab under-the-table stands, and so are difficult to remove. Because the thin-client workstations require a minimum of

processing power and RAM, Dvorak has an adequate number of backup workstations in the case of workstation failure. Network failure is addressed above (excluding the failure of a network interface in a workstation, which can be addressed by using a backup workstation until the network interface card can be replaced).

**Copyrights, fair use and Internet safety:** Since software is deployed centrally on the Edubuntu servers, rights management is simplified. This project relies on open source software, with usage covered by either GNU license or the Creative Commons license, which reduces the risk of copyright infringements. The only potential risk of copyright infringement relates to in-house development, which will be monitored by the technology coordinators as part of their system maintenance tasks. Workstations will be locked down and reset to default configurations each day to minimize the possibility of copyright problems arising from student use. Internet safety will be handled by existing CPS policy, including its filtering system and policies laid out in the Student Handbook.

**Data security:** The servers will not store sensitive data. Linux uses a powerful, industry-standard set of system and file permissions, which reduce the possibility of intrusion by unauthorized personnel. Students will not have a user id or password, or be aware of what the login user id / password combination is (logins will happen automatically). The number of people with system administration privileges will be kept to a minimum (two technology coordinators, two technology teachers, the principal and the assistant principal), Password standards for system administrators will be high (minimum 8 characters in length, including mixed case, at least one digit, and at least one non-alpha, non-numeric character). Passwords will not be physically stored in an identifiable format.

**Skill risk:** One additional area of security relates to the depth of skills available to maintain the thin client system and support teachers and students in its use. Because the Edubuntu thin client architecture is not supported by CPS's technology support services, Dvorak risks some exposure in the loss of support capacity in the event of losing the technology coordinators, since Linux server administration skills are not as common in the technology labor force as Microsoft server administration skills. This risk will initially be addressed by training the two technology coordinators, and providing training to the technology teachers in basic login and software features (see the Professional Development section below). Future technology coordinator hiring should include some Linux experience as an employment criterion. In addition, steps should be taken to build support skills among a student technology support group (e.g., the TechCrew program which will be beginning at

Dvorak in January, 2009). There is also an extensive Internet community around Ubuntu and Edubuntu which can be used for support assistance (and which may generally be more responsive than the CPS Tech-Excel service).

## **Professional Development**

**Technology coordinators:** Technology Coordinators will complete two online courses towards Ubuntu Certification:

Ubuntu Professional Course I

Ubuntu Professional Course II

The courses are offered by SavoirFaire Linux, a Ubuntu Training Partner (see <http://ubuntu.savoirfairelinux.com/elearning/> for more information).

The Technology Coordinators will train the Dvorak technology teachers in basic start-up troubleshooting and software operation for the lab courses. The Edubuntu distribution uses OpenOffice, which is similar to Microsoft Office XP in functionality and interface. Edubuntu uses Firefox as the web browser, so again, functionality will be similar to existing web applications.

**Budget**

<b>Item</b>	<b>Quantity</b>	<b>Unit Price</b>	<b>Ext Price</b>
<b>Hardware</b>			
Edubuntu server (see Appendix I for sample server configuration details)	3	\$3,000	\$9,000
1gb 24-port Ethernet switch	2	\$300	\$600
1gb 8-port Ethernet switch	1	\$100	\$100
<b>Cables, miscellany and spare parts (2 80gb drives, 1 switch plus contingencies)</b>			\$1,500
<b>Total hardware</b>			\$11,200
<b>Software</b>			
N/A			\$0
<b>Total software</b>			\$0
<b>Professional Development</b>			
<b>Technology Coordinators</b>			
Ubuntu Professional Course I	2	\$250	\$500
Ubuntu Professional Course II	2	\$250	\$500
<b>Technology Teachers</b>			
Substitutes	2	\$140	\$280
<b>Total training and professional development</b>			\$1,280
<b>Contingencies (10%)</b>			\$1,248
<b>Total</b>			\$12,480

**Budget notes:** A Request for Proposal (RFP) will be issued for the hardware portion of this project, so hardware amounts listed above are "not to exceed." Approximate amounts above are from Dell's website (<http://www.dell.com>) as of November 28, 2008. See Appendix I for the server specifications used to obtain the prices above. Ubuntu training prices are from the Internet, November 27, 2008. The substitute rate is the current (as of writing) CPS rate for certified substitutes. The budget includes funds to cover contingencies. Labor costs for installation and testing will be covered by the technology coordinators, so are not included in the budget. A formal Request for Proposal for the hardware appears in Appendix II.

### Network topology

#### Thin Client Computer Lab Project Network Diagram

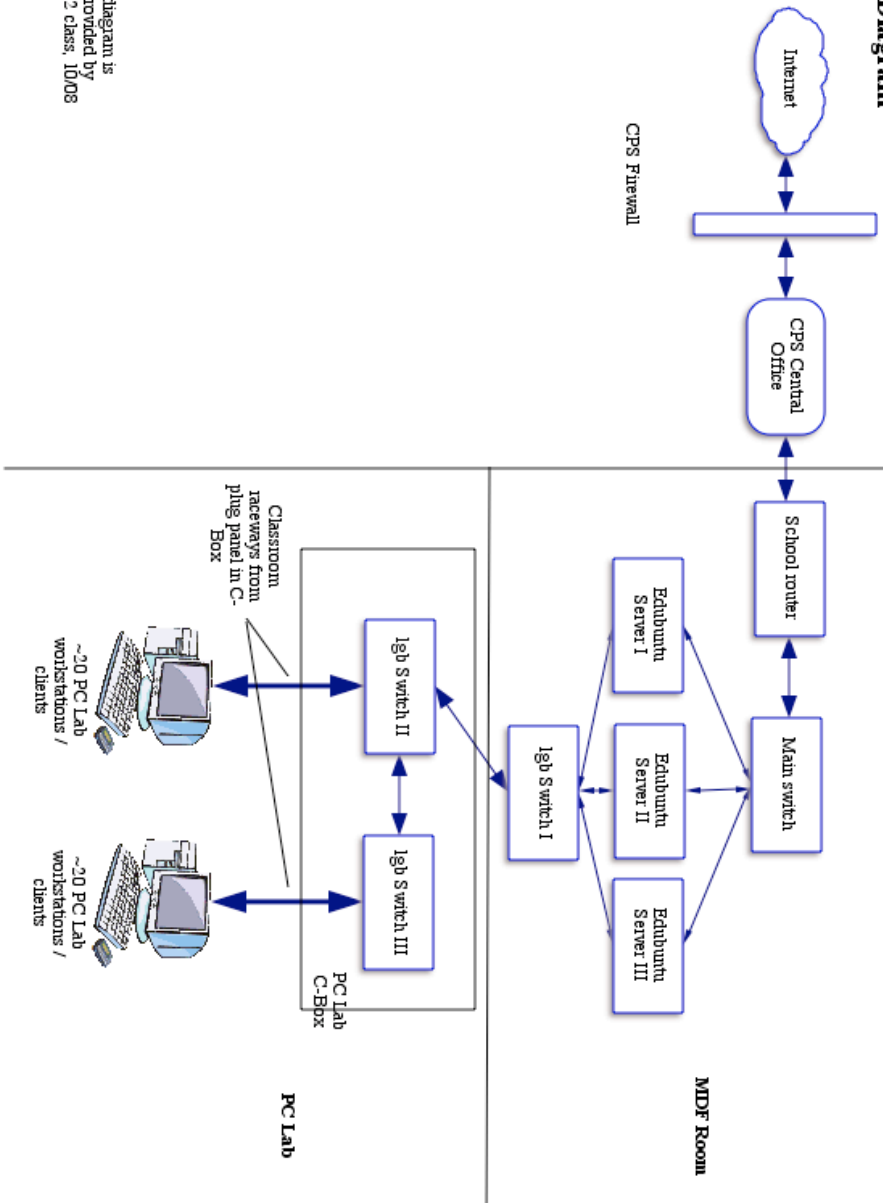


Diagram by Jim Davis. This diagram is based on network diagrams provided by Mitchell Marks to the TTE-532 class, 10/08

## References

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**Appendix I: Sample server configura**

**CPU:** Quad Core Intel® Xeon® E5440, 2x6MB Cache, 2.83GHz, 1333MHz FSB

**Memory:** 8GB 667MHz (4x2GB), Dual Ranked DIMMs

**Chassis Configuration:** Rack Chassis with Sliding Rapid/Versa Rails, Universal

**Disk Controller:** PERC 6/i Integrated Controller Card

**Hard Drive Configuration:** Integrated SAS/SATA RAID 5, PERC 6/i Integrated

**Primary Hard Drive:** 80GB 7.2K RPM Serial ATA 3Gbps 3.5-in HotPlug Hard Drive

**2nd Hard Drive:** 80GB 7.2K RPM Serial ATA 3Gbps 3.5-in HotPlug Hard Drive

**3rd Hard Drive:** 80GB 7.2K RPM Serial ATA 3Gbps 3.5-in HotPlug Hard Drive

**Network Adapter:** Intel PRO 1000PT 1GbE Dual Port NIC, PCIe-4

**CD/DVD Drive:** 16X DVD-ROM

A system with the above configuration was priced on Dell's website at \$2,827 on November 27, 2008.



## Appendix II: Request for Proposal

<School letterhead>

### Request for Proposal Thin Client Computer Lab Project

**Statement of Purpose:** Dvorak Technology Academy requests a proposal for equipment as described below to implement a thin-client computing laboratory for elementary and middle school students. This proposal applies to equipment and hardware maintenance and repair only, and does not request any additional services.

**Background:** Dvorak Technology Academy is a public pre-K through 8th grade school in Chicago's North Lawndale neighborhood.

**Point of Contact:** James Davis, Technology Coordinator  
Telephone: 773-534-1690  
Fax: 773-534-1674  
Email: [jdavis1@cps.edu](mailto:jdavis1@cps.edu)

**Scope of work:** Dvorak Technology Academy is converting its PC Computing Lab to a thin client network architecture. This change requires the addition of the following equipment:

3 servers meeting the following requirements:

- 4 gb or greater RAM
- At least one Intel processor with 2 or more cores running at 2.5 GHz or greater speed
- 80gb per server, RAID 5
- rack-mountable chassis
- two 1gb Ethernet interfaces per server
- no operating system installed
- minimum of 3 year warranty on parts and labor with next-day response parts replacement

2 1gb 24-port switches

1 1gb 8-port switch

#### Proposal requirements:

- Vendor must supply purchase price as well as three-year lease terms.
- Proposals must be submitted in a typed format to the contact person listed above by January 15, 2009.
- Proposal must specify system components, including manufacturer part number.
- Proposal must justify equipment selection in terms of performance and expected mean-time before failure.
- Vendor must be an approved Chicago Public Schools vendor. Proposals may be subject to review by

Chicago Public Schools Information Technology Services.

**Proposal Evaluation Process:** Proposals will be evaluated on price, support terms, component quality and component justification.

**Project timeline:**

January 15, 2009: RFP deadline

February 1, 2009: Award determination

March 1, 2009: Equipment acquisition deadline.

**Payment Schedule:** Equipment may be leased depending on the proposal. Payment or lease terms will begin within 45 days of equipment receipt.

<end>

### **Appendix III - Personal reflection**

The idea for this project grew out of an initial idea of creating a proposal for a networking laboratory for students that would use Linux as. I was not aware of how far and wide Linux had spread in the education world. My experience with Linux has primarily been a way of extending the useful life of otherwise obsolete PCs. It occurred to me that the same could also be done in the school environment, where we seem to be buried in aging PCs. The thin client architecture also was attractive because it centralizes and simplifies system maintenance.

My research turned up the Edubuntu project, which was attractive because it connected with an active community of educators who have been working with Linux and thin clients. This indicated a body of experience that could be tapped at every stage of the project process.

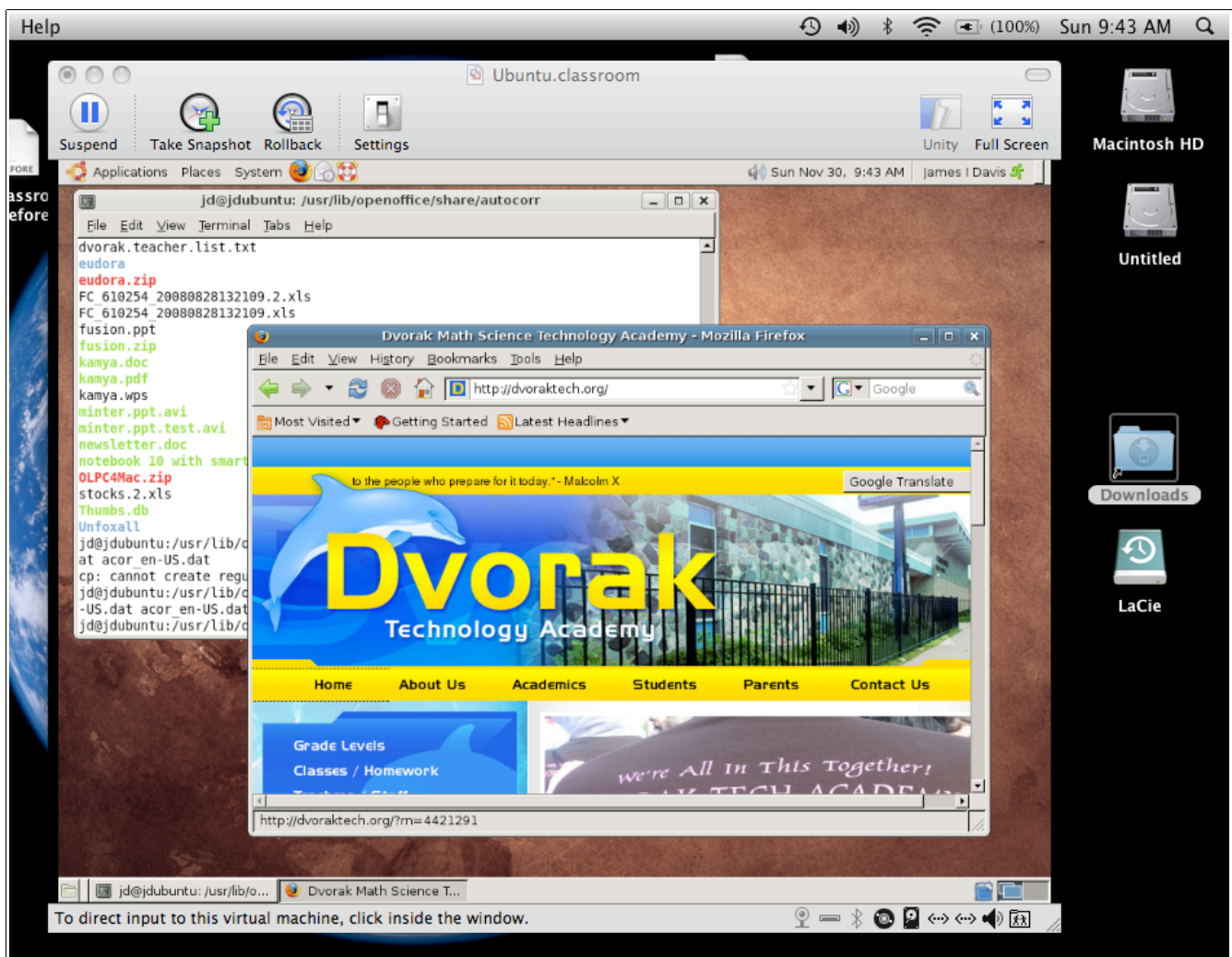
While I had some familiarity with older Linux installations (Slackware), I had never used Ubuntu, and was pleasantly surprised at how easy the installation process had become. It was very easy to get a Ubuntu installation up and running (although configuring a thin client system with a Macbook and emulation / virtual machine software was not so easy -- see Appendix IV for a write-up of the results of several hours of head-scratching, googling, code-scanning, configuring and booting).

My learning on this project took place in several areas: Macintosh networking support, configuring networking of virtual machines (in particular VMWare's Fusion), setting up DHCP options, general Unix routing and IP configuration, PXE and network booting, Linux installations, and practical experience in setting up a (very small) thin client network. I have a much greater understanding of Linux in the educational setting, especially Ubuntu (which I had never used before). While the preparation of this project proposal entailed some effort, I also set a running thin client network, giving a starting sense of how I might go about this at Dvorak (although there I would probably be testing on older equipment that has been pulled out of active duty).

### Appendix IV: Edubuntu setup notes

These are notes I have made on setting up a little demonstration of Edubuntu running in thin client mode on a Macbook. I use both "Ubuntu" and "Edubuntu" to refer to the server set-up. Ubuntu is a general Linux distribution, Edubuntu is a version of the Ubuntu distribution tailored for the education world. The initial installation was basically a Ubuntu thin client server installation, then enhanced with a bundle add-on education software. Once all of the software was installed, I considered the server an "Edubuntu server". These notes are both an attempt for me to collect what I did for future reference, and also to document what I did for others attempting something similar.

I have VMWare Fusion 2.0 installed on a Macbook with a 2.1GHz Intel dual-core processor and 2gb of memory running Mac OS X 10.5.5. I used VMWare Fusion for the virtual environment for running Edubuntu. (Other options include Parallels or the free Qemu.)



*Firefox running on Ubuntu running inside a VMWare Fusion 2.0 window on Mac OS X 10.5.5.*

I downloaded the *alternate* Edubuntu install could from <http://releases.ubuntu.com/8.10/> (look for PC (Intel x86) alternate install CD). The "alternate CD" includes a pre-configured thin-client installation option.

I burned a could from the .iso image file I downloaded, and used that with VMWare to create a new VM. I set the allocated memory to 512mb. I had to set the VMWare fusion preferences (Mac keyboard) to ignore Mac keyboard shortcuts, so I could access the function keys in VMWare. At the beginning of the install, I pressed Fn-Ctrl-F4 to select a menu of special installation choices, and I selected the LTSP Server option. LTSP is an acronym for the "Linux Thin-client Server Project".

I ran the LTSP Ubuntu install, and updated all of the installed software. With the Ubuntu server still running, I inserted the "Education Add-on CD" (also downloaded as an .iso file and burned to a CD) and installed the rich set of educational software available via the add-on CD.

This left me with a functioning Ubuntu system. I could login and perform all of the normal computer operations in Ubuntu, inside of a VMWare window on the Macbook.

The Edubuntu system I want to set up will provide boot instructions to the clients. When the clients boot up, they will use PXE (a standard feature on most PC network interfaces now) to find a boot server on the network (which will be the Edubuntu server).

This means that the Edubuntu server needs to run DHCP, but I don't want the Edubuntu server to serve addresses to the rest of my live network (66.nnn.nnn.192/224), which already has a DHCP server serving it -- I only want the Edubuntu DHCP service to serve a private network segment of thin clients.

A "real" Edubuntu server, as described in the project description, will have two NICs or a card with two ports. One port is connected to the public / live network and from there to the Internet. The second port is connected to the private segment of thin clients. However, any network requests from the thin-client segment should be routed to the network on the other port (which includes the outside world as well). While I don't have two Ethernet ports or network cards on the Macbook, I do have two live network interfaces on the Macbook – the Ethernet port (device name en0 on the Mac, which can be found on the "About This Mac" form, aka System Profiler, under the Apple menu) and the Airport wireless connection (en1), so it seemed possible to emulate the desired server configuration using the Macbook on my home network.

Having the Macbook use the two adapters as I wanted turns out to be relatively simple *once the*

*VMWare environment is set up to support two network interfaces.* I emphasize that second part because VMWare's Fusion product is designed for ease of use and does not provide a straightforward way to support multiple hardware adapters. Fusion can support multiple *virtual* adapters on the same physical adapter, but telling it to support a second hardware interface required modifying the Fusion boot script (Fusion is, after all, running in Mac OS X, essentially a Unix environment) and a support file (called `locations`), and the settings file for the Edubuntu virtual machine (in 2.0, this is a file with an extension of `.vmx`, located within the `.vmwarevm` package (right-click on the package and select "Show package contents" to find the file). Instructions for making these modifications were for the most part available from the Internet (Parsons, 2007, both the white paper and subsequent posts), with some custom adaptations by me for my equipment and network.

1. Modify the `boot.sh` script to assign the `en0` interface (the Ethernet adapter) to a new virtual adapter, `vmnet2`, and to use `en1` (the wireless adapter) as the default adapter. The new lines are:

```
# Create virtual interface for my new vmnet2 (bridged)
"$LIBDIR/vmnet-netifup" -d /var/run/vmnet-netif-vmnet2.pid vmnet2 vmnet2

# Configure virtual interface 'vmnet2'
eval 'hostaddr="$vmdb_answer_VNET_2_HOSTONLY_HOSTADDR"'
eval 'netmask="$vmdb_answer_VNET_2_HOSTONLY_NETMASK"'
ifconfig vmnet2 inet "$hostaddr" netmask "$netmask"

# vmnet-bridge puts itself in background (daemon mode)
# Bridge to host network interface 'en0'.
#"$LIBDIR/vmnet-bridge" -d /var/run/vmnet-bridge-vmnet0.pid vmnet0 en0
# Bridge to the primary host network interface (which can change over time).

"$LIBDIR/vmnet-bridge" -d /var/run/vmnet-bridge-vmnet0.pid vmnet0 ''
"$LIBDIR/vmnet-bridge" -d /var/run/vmnet-bridge-vmnet0.pid vmnet0 en1
"$LIBDIR/vmnet-bridge" -d /var/run/vmnet-bridge-vmnet2.pid vmnet2 en0

vmware_stop_pidfile /var/run/vmnet-bridge-vmnet2.pid || true
```

(See Parson's instructions for more information on making these changes.) In the above, Fusion applications are called to link `vmnet0` to `en1`, the Airport wireless adapter. The new `vmnet2` virtual adapter is linked to `en0`, the Macbook's wired Ethernet adapter. The values like `VNET_2_HOSTONLY_HOSTADDR` and `VNET_2_HOSTONLY_NETMASK` come from the `locations` file.

2. Modify the `locations` file to tell it what IP address and network details to use for the adapter (in my case, the 192.168.1 network; the `vmnet2` address was set to 198.168.1.9):

```
answer VNET_2_HOSTONLY_HOSTADDR 192.168.1.9
answer VNET_2_HOSTONLY_NETMASK 255.255.255.0
answer VNET_2_HOSTONLY_SUBNET 192.168.1.0
answer VNET_2_DHCP no
```

Note that I do not want VMWare to provide DHCP services on the adapter. I will manually assign a 192.168.1.0 network address to the Edubuntu server.

3. Change the VMWare Settings for the Edubuntu server to support two network adapters (in Fusion, select the Edubuntu virtual machine, click on Settings, click on Network, click on the + button to add adapters).
4. Modify the `vmx` file (see above for location) using a text editor like TextWrangler to tell VMWare Fusion to assign Ethernet1 to the `vmnet2` virtual adapter. Change the properties of the `ethernet1` adapter to:

```
ethernet1.present = "TRUE"
ethernet1.connectionType = "custom"
ethernet1.vnet = "vmnet2"
```

I am telling VMWare that this is a custom connection type, that the adapter is present, and that I want to use the `vmnet2` adapter that is created in the modified `boot.sh` script above.

After making the changes, the VMWare program should be restarted from the Terminal window to make sure everything works properly:

```
$ cd /Library/Application\ Support\VMWare\ Fusion
$ sudo ./boot.sh --restart
```

(Again, I am indebted to Parson's instructions for the above.)

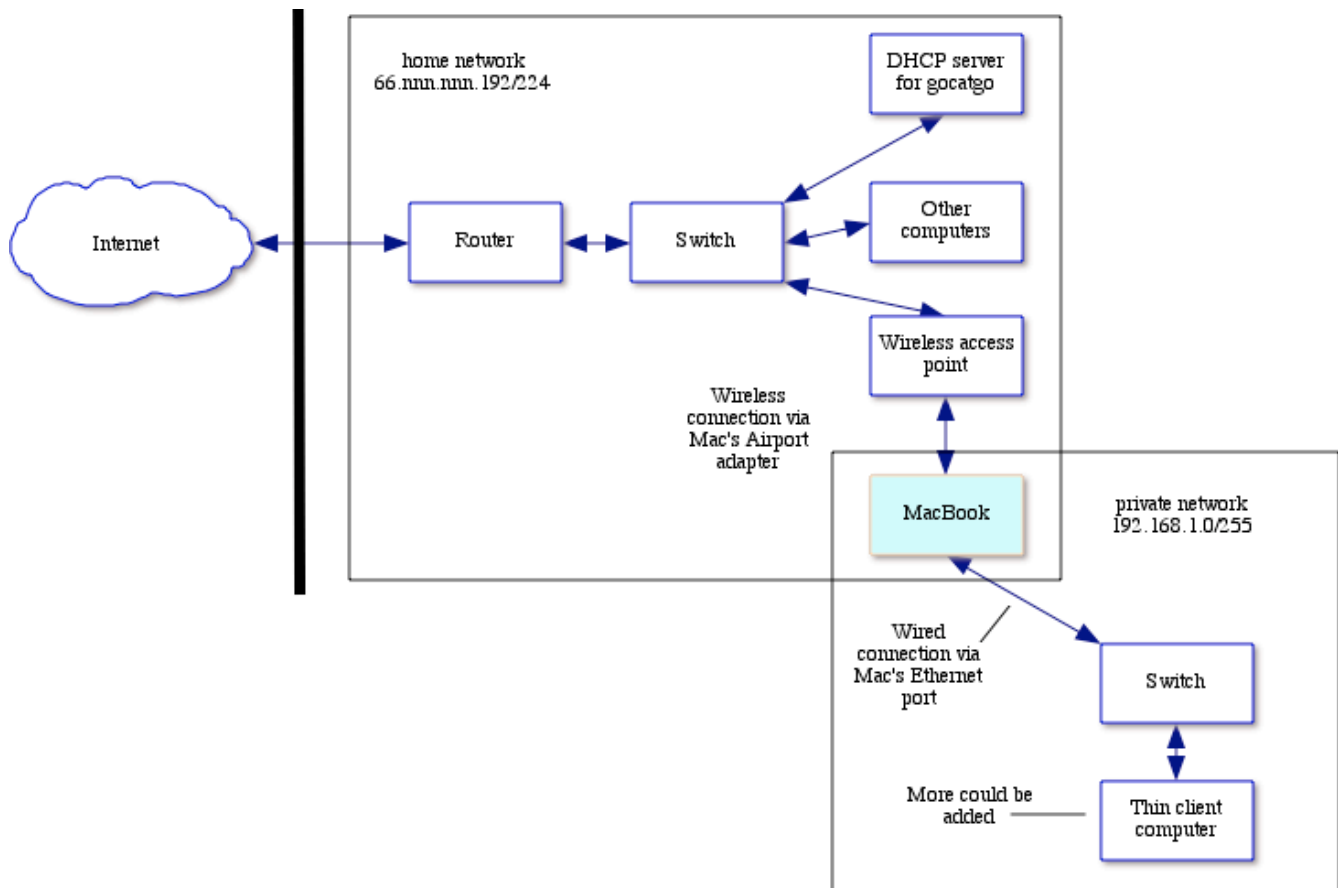
I also had to make changes on the Macbook for the adapter configuration. In the System Preferences application, I selected Network and did the following:

1. Change the Service order so that the Airport adapter takes precedence (click on the gear button in the lower left corner of the screen, select Set Service Order..., and move Airport above

Ethernet).

2. Select the Ethernet adapter, and change it to Manually configured. Enter an IP address in the 192.168.1.0/0 range, but *not* the same number as was assigned to the VMWare adapter in the `locations` file above. I used 192.168.1.8. The netmask should be the same as the `locations` file setting (255.255.255.0). I also set the DNS servers to be the same as used by Airport, but I do not know if that step is necessary.
3. Click Apply to make the changes.

In the System Preferences: Sharing application, I turned on Internet sharing, sharing the connection from the Airport to the Ethernet port. This was so easy to do, I am embarrassed about how much time I spent looking for instructions on routing between two network connections on the Mac. See below for a diagram of the network setup.





*Image 2: A diagram of the test network.*

---

I also needed to tell the Edubuntu server how to use the network connections. This also involved a few steps:

1. Change the network interfaces file to tell it about the additional network adapter. I edited the `/etc/network/interfaces` file to add the following section:

```
# Ethernet connection to private network
auto eth1
iface eth1 inet static
address 192.168.1.10
netmask 255.255.255.0
network 192.168.1.0
broadcast 192.168.1.255
#gateway 192.168.1.1
```

The last line is commented out because I was not sure what to put there, and the value there did not work. Without an explicit gateway setting, the installation worked fine.

The `dhcpd.conf` file also needed to be changed to accommodate the network range that I had chosen. The new file contains the following:

```
subnet 192.168.1.0 netmask 255.255.255.0 {
    range 192.168.1.20 192.168.1.200;
    option domain-name "dvoraktech.org";
    option domain-name-servers 192.168.1.1;
    option broadcast-address 192.168.1.255;
    option routers 192.168.1.1;
    next-server 192.168.1.10;
    option subnet-mask 255.255.255.0;
    option root-path "/opt/ltsp/i386";
    if substring( option vendor-class-identifier, 0, 9 ) = "PXEClient" {
        filename "/ltsp/i386/pxelinux.0";
    } else {
        filename "/ltsp/i386/nbi.img";
    }
}
```

The `dhcpd.conf` file is located in the `/etc/ltsp` directory. The range is set to be 192.168.1.20 to 192.168.1.200, to leave room for servers and other devices at either end of the range. The domain name is arbitrary in this test case. The routers setting is probably not correct, but doesn't seem to matter in this case since the clients are not actually using the setting (the Edubuntu server is doing the work, not the workstations, which are basically dressed up dumb terminals). The `next-server` setting needed to

be set to the IP address that the Edubuntu server is using. The other settings are automatically installed by the LTSP Ubuntu installer, and refer to the image file that is provided to network boot clients.

The network service and the DHCP service need to be restarted after modifications are made to their respective configuration files:

```
$ sudo /etc/init.d/networking restart
$ sudo invoke-rc.d dhcp3-server restart
```

The SSH keys also need to be regenerated after changing things like IP addresses, and the image file served up by the DHCP server also needs to be rebuilt:

```
$ sudo ltsp-update-sshkeys
$ sudo ltsp-update-image
```

Before testing the thin client operation, I tested the network connectivity and the ability of a PC on the private segment to connect to the outside world. I attached a Dell Inspiron 300 laptop with an Intel Pentium M processor clocked at about 600mHz (the computer adjusts CPU speed) with 384mb of memory running Windows XP Professional over a 100mbps Ethernet connection. I assigned an address manually in Windows's network configuration dialog, along with DNS servers, and was able to ping the Edubuntu server (192.168.1.10), the Macbook address on the virtual adapter (192.168.1.9), the assigned Macbook Ethernet address (192.168.1.8), as well as the Macbook Airport adapter IP address (66.nnn.nnn.206, assigned by a DHCP server on the home network), as well as other machines on the home network and IP addresses of systems on the Internet (e.g. [www.gocatgo.com](http://www.gocatgo.com) hosted by Godaddy). Firefox was able to access web pages on the Internet. This assured me that the Macbook was successfully sharing its Internet connection. This setup is like a NAT network, except the "translated" addresses are being assigned by the Edubuntu DHCP server (which I need to send to the clients the boot image).

I then rebooted the Dell laptop and pressed F12 to select boot options. The Dell provides a PXE network boot option. I selected that, and the laptop found the Edubuntu DHCP server, and began its negotiations with the server. Details on the negotiations are described in the Edubuntu Documentation Project (2006) pages. After a few seconds, the Ubuntu graphical login page appeared on the laptop. I logged in, and was "thin client computing." This Appendix in fact is being written on the Dell laptop thin client using OpenOffice 2.4 served up by an Edubuntu server running inside VMWare Fusion on a Macbook. I was even able to copy my auto-corrections settings from the Macbook to the appropriate location on the Edubuntu server, and use my auto-corrections as I type this.

The above exercise demonstrates that the thin client setup will work, and provides a means for evaluating and experimenting with software available with the Edubuntu distribution and the “add-on” education CD. It also provides a relatively mobile testbed for testing the appropriate mix of terminal settings for a school computer lab (e.g., lockdown methods), as long as a wireless connection, switch and a computer capable of being used as a workstation are available. Next steps include testing workstation configuration settings, stress testing a server, determining what constitutes the minimal workstation configuration that still yields acceptable lab use performance, installation on a server-class machine to assess performance, and other boot options for workstations (e.g., CD or an image on the hard disk).