Setting up your Virtual Machine on the Fossil Server

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For this course, each student will need a virtual machine on which to build, modify, and test Linux kernels. Project assignments require you to learn how to build a new version of the kernel, to add new service calls to the kernel, and to create a message system to transmit messages among Linux processes using the facilities of the kernel.

There are two options for running your virtual machine:

- Use your own personal computer or Macintosh and install one of the VMware products on it — VMware Player or VMware Workstation (on Windows or Linux), or VMware Fusion (on the Macintosh). VMware Player is free, and student discounts apply to the other products. Instructions for this option can be found here: [doc, pdf]
- Use the virtual Fossil server in the Computer Science Department, as described in this document.

The same virtual machine is supported in both options.

Virtual Machines

A virtual machine is an application program capable of simulating a computer system with enough fidelity and performance to mimic the actual hardware. The virtual machine concept originated in the 1960s, and it has now matured to the point where virtual machines are routinely used in a wide variety of commercial and organizational settings.

Two important terms in virtual machine technology are host and guest.

- The host is the hardware and operating system on which the virtual machine application runs — e.g., your own computer, a laboratory computer, or a departmental or corporate server. The host operating system is irrelevant, so long as it supports the virtual machine application. Sometimes the host system has no formal operating system of its own and, instead, runs the virtualization application directly on “bare hardware.” In this case, the virtualization application is called a hypervisor.
- The guest is the simulated computer. It runs its own operating system and set of applications — e.g., a Linux guest running on top of Windows or Mac-OS host.

The virtual machine application uses the host processors to simulate the guest processors, and it uses files on the host system to simulate the disks and RAM of the guest system. It
also connects some host resources directly to the guest system — e.g., the host’s CD or DVD drive or a USB flash drive when it is plugged into the host system.

A goal of this Operating System course is to provide experience in working directly with the inner layers of a real, widely used operating system. You will be exposed both to the breadth and depth of such an operating system and also to many of its gory details. In order to do this, a safe place must be provided for you to work — a place where you can make mistakes, crash your operating system, corrupt disks and data structures, etc., without harming anyone else and even without harming your own, working computer.

The virtual machine provides this kind of environment. For this course, we provide a dual processor virtual machine with OpenSUSE Linux version 11.4 already installed.

Fossil Lab and the Virtual Fossil Server

The WPI Fossil Lab (Free Open-Source Software Laboratory) was created in the early 2000’s as a laboratory in which students could build, modify, and experiment with operating systems on dedicated hardware. In late 2007, the Fossil Lab hardware was upgraded to dual-core Intel Pentium PCs, each with VMware Workstation installed. From then until the end of the academic year 2010-2011, undergraduate operating system project assignments were based exclusively on VMware virtual machines. Students had the option of working in the Fossil Lab or on their own desktop or laptop computers.

The Fossil Lab has now been retired and the Computer Science Department is reallocating the space for other purposes. In its place, a modern server computer has been acquired, known as the Virtual Fossil Server, and connected to the WPI network under the name

fossilvm.cs.wpi.edu

This server contains two AMD 4184 processors with six cores each operating at 2.8 GHz, 64 gigabytes of RAM, and a 5-terabyte, 12-disk RAID system for storing user data and students’ virtual machine images. It is estimated that this will provide enough computing power and storage for about half of a normal CS-3013 class.

Your Virtual Machine on the Virtual Fossil Server

There are three parts to setting up and using a virtual machine on the Virtual Fossil Server. First, a clone needs to be made from the template provided for this course. Second, the machine has to be started and a viewer has to be opened so that the user can select a kernel to boot. Third, the user should create a remote desktop on the virtual machine once it has booted. The third part is necessary because the viewer from the second part does not have sufficient interactive performance to be usable for serious project work.

Before undertaking these three parts, however, you will need the following installed on your own desktop or laptop, so that you can access the Fossil server and guest system:

- A secure shell client such as PuTTY for Windows or a secure shell window for Linux and Macintosh systems. By default, Linux and Macintosh systems come with secure shell applications. PuTTY can be downloaded from here:
  http://www.wpi.edu/academics/CCC/Help/Software/putty.html
- An X11 window “server” — that is, an application that runs on your desktop or laptop and that allows remote programs to display their window on your computer.
These are built into Linux and Macintosh systems by default. For Windows, the X-Win32 application can be downloaded from here:

http://www.wpi.edu/academics/CCC/Help/Software/xwin.html

Other X11 window servers are also available for Windows platforms.

- An application called Free NX client, which provides a high-performance desktop interface to your virtual machine. This is available for Windows, Linux, and Macintosh platforms and can be downloaded at no cost from here:

  http://www.nomachine.com/download.php

You should install all three of these and make sure they work before proceeding any farther.

Cloning a Virtual Machine

To create your virtual machine, you will make a clone of the existing virtual machine provided for this course. Using PuTTY or your secure shell application, log into

fossilvm.cs.wpi.edu

using your WPI user ID and the temporary password provided to you. You will be asked to change your password immediately upon logging in.¹

Choose a name for your virtual machine that identifies it as yours. Execute the shell script

sudo clone-vm.sh <your virtual machine name>

This will make a copy of the course virtual machine, assign your chosen name to it, assign a new MAC address,² and register the name with the internal Domain Name System (DNS) of the Fossil server.

Note 1: Root privileges are required to create virtual machines in the Linux KVM system. The sudo system of fossilvm.cs.wpi.edu has been configured so that students have limited root privileges — specifically, the privileges to run the command scripts of this document. The first time you invoke sudo, it will ask you for your password. This password will be valid for a reasonable period of time, but after a while, it will ask you for your password when you try to use sudo again.

Note 2: The Fossil server maintains an internal private network to which all virtual machines are connected. Your virtual machine is not directly visible from the wider WPI network, and its name is not known in the WPI naming system. All connections to your virtual machine will be made through a proxy, which also resides on the Fossil server.

Cloning takes about 30 seconds, most of which time involves making a copy of the image of the virtual disk. The following is a sample of a shell script cloning a virtual machine:

¹ If you forget your password, the Professor or TAs can reset it for you.
² MAC addresses are the hardware addresses that Ethernet devices use to communicate with each other. MAC stands for “Media Access Code.” Very bad things happen if two devices with the same MAC addresses are connected to the same local area network.
student2@FOSSILVM:~$ sudo clone-vm.sh student2-vm
[sudo] password for student2:
Allocating 'student2-vm.qcow2' | 14 GB   00:32

Clone 'student2-vm' created successfully.
Domain student2-vm started
student2@FOSSILVM:~$

The last line indicates that the system has started the virtual machine. This is equivalent to pressing the boot button on a hardware machine that had been switched off. A boot loader is read from the virtual hard drive and a boot timer is started. If you take no action, the boot loader selects and loads the default kernel of your virtual machine.

If you have not already done so and are working on a Windows computer, start X-Win32 or your X11 server program now. (This is started automatically on Linux and Macintosh systems.)

Next, in the secure shell window, type the command

    sudo view-vm.sh <your virtual machine name>

This opens a view of the console of the guest system. If you were able to do this quickly enough, an X11 window will open a window on your desktop resembling Figure 1 on page 5, showing the boot screen of the guest system. Use the arrow keys to (a) stop the boot timer and (b) to select the kernel you wish to boot.

When you have selected the kernel you wish to boot, press Enter to actual boot it. This will eventually bring you to the desktop login screen, shown in Figure 2 on page 6.

If you do not stop the boot timer before it expires, it will cause the default kernel of your guest system to boot.
If ever you find that you were not quick enough to stop the boot timer, you can pull down a menu from the **Menu** button in the lower left corner of Figure 2. This brings up the small guest system menu shown in Figure 3.

Select **Shutdown**, which brings up another menu. In that menu, select **Restart Computer** to start the boot process and boot timer all over again. While the display is repainting itself, press the up- and down-arrow keys to stop the boot timer. Then, select the kernel you wish to boot and press **Enter**.

Other boot options can be typed into the **Boot Options** line at the bottom of Figure 1. However, we will have no need of them in this course.
Creating a Remote Desktop on your Virtual Machine

While it is possible to log into the virtual machine and open a desktop using the login prompt in Figure 2, it is not advisable. The interactive performance of the viewer of Figure 1 and Figure 2 is poor, it misses keystrokes, and the mouse and cursor are difficult to control. Instead, you should open a remote desktop on your virtual machine using the Free NX Client that you previously installed.

Start the Free NX Client. Figure 4 shows its appearance in Microsoft Windows. The Macintosh and Linux versions have slightly different appearances, but the information contained is the same. Enter a name into the box labeled Session to help you identify which virtual machine you are connecting to. A good session name is that of the virtual machine itself — i.e.,
what you created in the clone-vm.sh step above. Do not enter the Login name or Password yet.

Click the Configure button to bring up the configuration panel shown in left of Figure 5 below. Type the exact name of your virtual machine in the Host field. In the Desktop area of the panel, select Unix for the type of desktop in the left pull-down menu and KDE for the type of desktop environment in the center pull-down menu.
Move the slider of this panel to indicate the kind of network you are on. For example, if you are connected via the WPI campus network, select LAN. If you are connected via a broadband internet connection from off-campus, select WAN, etc. In the area of the panel labeled Display, choose display size to fit comfortably on the screen of your computer display.

Next, select the Advanced tab at the top of the left panel of Figure 5 to display the right panel of Figure 5. Make sure that the box labeled Connect through a HTTP proxy is checked, and click the Settings button. This brings up another window, shown in Figure 6. Enter the name *fossilvm.cs.wpi.edu* as the HTTP Proxy Host, and enter 8080 as the Port. No user name or password is required for this proxy host. Click okay.

![Figure 6](image)

A proxy host is a computer or network device that makes connections from one network domain to another in situations where those two networks cannot communicate directly. In the case of the Virtual Fossil Server, the internal network connecting all of the virtual machines is not visible from the rest of the WPI campus network. However, the Fossil server listens to port 8080 and interprets the contents of those packets as intended for its internal network.

Moreover, the name of the virtual machine is not a legitimate, registered computer name on the WPI campus network. It is known only on the internal Virtual Fossil network. As a result, the name of the virtual machine in the left panel of Figure 5 is meaningless to the WPI campus network, but it is meaningful within the Fossil proxy host.

Now that you have configured your Free NX Client, click Okay in Figure 6 and click Save and then Okay in Figure 5. Your configuration is now saved, and you should not have to enter it again for this virtual machine. If you create another virtual machine with a different name, you need to repeat these steps. The Free NX Client can support multiple configurations via the pull-down Session menu in Figure 4.

**Logging into your Virtual Machine**

You are now ready to log into your guest operating system running in your virtual machine. This virtual machine is pre-configured with one user having the login ID student and password “CS-3013/502” (without the quotes). Enter these into the Login and Password boxes of Figure 4 and click Login. Free NX Client will go through a sequence of information boxes, including a request to accept a security key, and eventually it will open a window containing a KDE remote desktop of the guest system resembling Figure 7.
This is the SUSE Linux equivalent of the Windows desktop, and it is used much the same way. In particular, note the little green “Gecko” icon in the lower left corner. This is functionally equivalent to the Start button in Windows. Click it to get a two-dimensional menu of program items and other commands.

Note: This desktop is completely independent of any desktop that would have appeared if you had logged into the virtual machine via the viewer in Figure 2. By default, Linux supports multiple users logged in at the same time, each with his/her own desktop. Moreover, if you are working in a team, each team member may log into the same virtual machine, even at the same time.

Note: It takes a minute or so for the name of your virtual machine to propagate through the Domain Name System (DNS) of the Fossil Server. If Free NX Client complains that it cannot find your virtual machine, check the details in the error message dialog box, wait a minute or so, and try again.

Click on the “Gecko” button and select the Terminal command from the first menu. This brings up a Linux command shell. You can do all of the usual things in this shell. For example, Figure 8 below shows the hostname command, which reports the name of the virtual machine created in the clone-vm.sh step on page 3. It also shows the IP address of this
virtual machine, which is in the private network of the virtual Fossil Server, along with the `uname` command showing which operating system kernel is running.

```
student@student2-vm:~$ hostname
student2-vm
student@student2-vm:~$ ip address
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 16436 qdisc noqueue state UNKNOWN
   link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
   inet 127.0.0.1/8 brd 127.255.255.255 scope host lo
   inet 127.0.0.2/8 brd 127.255.255.255 scope host secondary lo
   inet6 ::1/128 scope host
tvalid_lft forever preferred_lft forever
2: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP qlen 1000
   link/ether 00:16:36:5f:99:34 brd ff:ff:ff:ff:ff:ff
   inet 192.168.122.101/24 brd 192.168.122.255 scope global eth0
   inet6 fe80::216:36ff:fe5f:9934/64 scope link
   valid_lft forever preferred_lft forever
student@student2-vm:~$ uname -a
Linux student2-vm 2.6.37.5-0.5-desktop #1 SMP PREEMPT 2011-04-25 21:48:33 +0200 i686 athlon i386 GNU/Linux
```

**Figure 8**

Creating a user identity for yourself

Our version of the virtual Fossil Server is not very secure, and it is possible for students to accidentally or deliberately connect to the wrong virtual machines. Therefore, it is essential that you create your own user identity and password and that you change the root password of your guest system.

**Note:** In modern versions of Linux, you rarely have to log in as root. Most of the time, you should log in as a non-privileged user and use the `sudo` command to invoke root privileges where needed. This avoids accidents that are typical in most system development environments. As a helpful hint, KDE configures the user root with a distinctive desktop background that contains warning signs and images of bombs.

To manage user identities, invoke YaST, the system administration tool, to configure the user and group settings. Click the **Start** button in the lower left corner, select the third submenu, labeled **Computer** as shown in Figure 9 below, and select the **YaST** command.

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3. So far as I can tell, YaST stands for Yet another System Tool.
YaST will first ask you for the root password. This is CS-3013/502, the same as the password for the user named student. It will then bring up the YaST window, shown in Figure 10.
Select Security and Users from the left panel and User and Group Management from the right panel. Follow this GUI to create a new identity for yourself and/or to change passwords. We suggest that you use your WPI e-mail identity. Also, be sure to change the password for root. **Do this now!**

Log out, and then log in with this new identity, and finally use YaST again to delete the student identity.

*Changing the Display Size*

It is a nuisance to try to work with a virtual display of the guest system that does not fit into a window or on the screen of the host system. If you wish to change the display size of the guest, invoke the Configure Desktop command from the Start menu of Figure 7. This brings up a window resembling Figure 11:-

![Figure 11](image)

Select Display and Monitor in the Hardware section to tell KDE the size of the display. Finally, select Application Appearance in the top section, which opens a window with a lot of options. Select Fonts from the left panel. This lets you set the font sizes for most of the window characteristics. To change the background wallpaper of the desktop, right click in an empty area of the desktop and choose Desktop Settings from the menu. Select an image and apply it.
Feel free to experiment with other settings of this desktop.

**Useful Feature**

Because the *Free NX Client* is an *X11* application, it has the same properties as other *X11* applications that you may be using on your computer. In particular, you can cut, copy, and paste text between the host and guest system. This proves to be very handy.

**Shutting down and Rebooting**

By experimentation with the remote desktop, it seems to be the case that the *Shutdown* and *Restart* commands in the “Gecko” menu do not actually shut down or restart the guest system. It is not clear what the reason is.

If you experience this problem, the way to shut down or restart your virtual machine is to re-open the viewer (i.e., *not* the remote desktop) using the

```
    sudo view-vm.sh <your virtual machine name>
```

command. Then, in Figure 2, click the *Menu* button and select the appropriate command from the menu of Figure 3.

**Disaster Prevention**

During the first few terms when we used virtual machines in Operating Systems courses, students stumbled on a number of idiosyncrasies that rendered their virtual machines totally inoperable, trapping their work inside. As we have refined this course, this kind of disaster occurs less and less frequently.

*Nevertheless, it is always a good idea to back up your own work.* The best way to do this for guests running in the Virtual Fossil Server host is to e-mail files to yourself and/or to transmit them via a web browser or by a secure copy program. For example, you can open the *Firefox* browser by clicking on the bottom bar of the desktop, open a web page on your mail server, and e-mail yourself a file.

**Conclusion**

That’s it. Enjoy your virtual machine. You are now ready for your first kernel project.

This is the first term that we have introduced the Virtual Fossil Server for use in the Operating Systems courses. Please provide feedback and reports of difficulties.