CS-3013 and CS-502(EMC)
Operating Systems, Fall 2009

Setting up your Virtual Machine

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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.

Most undergraduate students will work in the *F*ree, *O*pen-*S*ource *S*oftware *L*aboratory — commonly known as the *Fossil Lab*. This is located in B17 Fuller Labs — i.e., in the basement behind the main staircase. Students who are registered for this course should be able to unlock the Fossil Lab door with their student ID cards.[1]

Graduate and corporate students will use one of the *VMware* products on a personal or corporate laptop, desktop, or server computer. Your virtual machine will be distributed as a zip file on a DVD on the first day of class. Some undergraduates may also prefer to work this way on their own laptops or desktops.

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 that virtual machines are used in a wide variety of commercial and operational 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 or a *Fossil Lab* PC or your corporate server. The host operating system is irrelevant, so long as it supports the virtual machine application.
- The *guest* is the simulated computer, which runs its own operating system and set of applications — e.g., Linux running on top of Windows or Mac-OS.

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 — e.g., the host's CD or DVD drive or your USB Flash drive when you plug it into the host.

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[1] An unavoidable problem is that it takes a long time to enable the ID cards of students who register for CS-3013 near or after the start of the term. If this affects you, get a friend to let you into the Fossil Lab.

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 11.1* already installed.

VMware Workstation, Player, and Server

This course uses virtual machine applications provided by *VMware, Inc. VMware* is a company that makes and sells virtualization systems for commercial and scientific applications.

VMware Workstation is a virtualization application designed for Windows and Linux personal computers. It can be used to create new virtual machines and to run existing virtual machines. It supports dual processors, multiple disks, network connections, and a variety of peripheral devices common to modern PCs. It includes the ability to take snapshots of a virtual machine and to roll the state of that machine back to the snapshot. It also includes the ability to clone a virtual machine — i.e., to make an exact copy of it. *VMware Workstation* is installed on the PCs of the Fossil Lab. (*VMware Fusion* is a similar product for the Mac.)

VMware Player is a freeware subset of *VMware Workstation* that is designed to run virtual machines that were created under some other *VMware* system. It does not have all of the capabilities of *VMware Workstation* — particularly the ability to take snapshots and roll back to them. However, it is free, and it is adequate for the purposes of this course.

VMware also makes a number of server products, including the free *VMware Server*. In order to use one of the servers, you will need a desktop application called *VMware Client*, which provides an interface to your virtual machine running on the server. If you plan to use a corporate *VMware* server, consult your site administrator with regards to the client.

Installing your virtual machine

There are three parts to setting up your virtual machine:–

- Copying the course version of the virtual machine to a hard drive or to your Fossil Lab home folder;
- Editing or adjusting the properties of your virtual machine as needed; and
- Booting the virtual machine for the first time, connecting it to the network, and creating an identity for yourself

Obviously, you may recreate your virtual machine often as you need to. In particular, if you really mess up, the easiest thing may be to throw it away and install another.

Installing your virtual machine in the Fossil Lab

The host operating system on the Fossil Lab PCs is Windows XP. At the start of the term, will receive a login ID and password for the Fossil Lab. This login is valid for all Fossil Lab PCs as well as the Fossil server (a Linux server). When you login in for the first time, you should change your password to something you can remember. Changing your password on one Fossil PC automatically changes it for all Fossil PCs and also for the server.

When you log in, you will find on your desktop two remotely mounted disks. The **H** drive is your home directory. It lives on the Fossil server and follows you to whichever Fossil PC you log into. Your Fossil **Desktop** is a folder within your **H** drive. The **P** drive is the (read-only) public directory for all Fossil Lab users[2].

In the Windows explorer on the host system, navigate to the folder

P:\CS-3013\A-term_2009\SUSE_Linux_11.1

and double-click to open the file **SUSE_Linux_11.1.vmx**. This is a file of type *VMware virtual machine configuration*, and opening it will start *VMware Workstation.*[3] You will see the *VMware Workstation* main window, which resembles the following:–

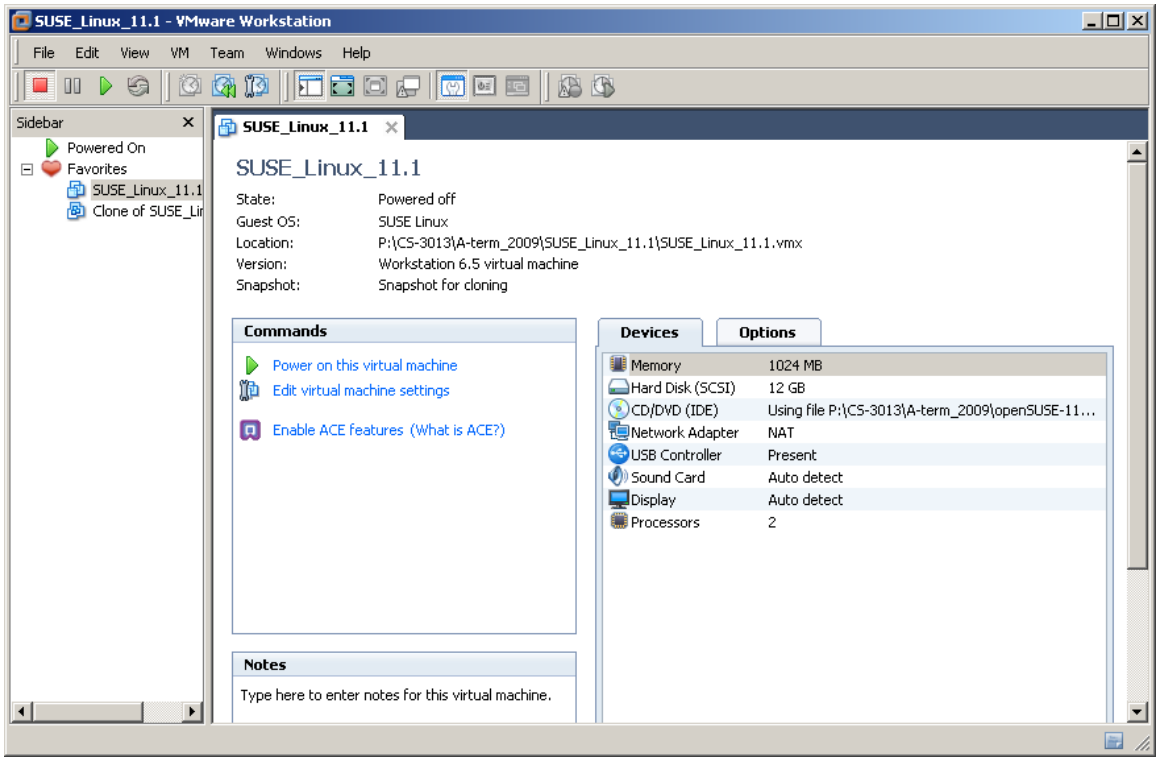

Figure 1

This shows the master virtual machine for this course. Note in the panel on the right that the virtual machine has 1024 megabytes of RAM memory, a 12 gigabyte hard disk, a CD-DVD drive mapped to the installation DVD of *openSUSE 11.1*, an Ethernet interface, a USB controller, and two processors. The entire virtual machine is described in the *VMware virtual machine configuration* file that you just opened, which is a text file. You may peruse it if you wish, but there is no need for you to edit it directly.

This virtual machine is read-only, so you cannot use it directly. Instead, you must make a *clone*. Select the **Clone…** command from the **VM** menu. This brings up the *Clone Virtual Machine Wizard*. Click **Next** in the Wizard window and again in the *Clone Source* window that follows. Eventually, you will see the *Clone Type* window shown in Figure 2.

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2 On the Fossil server, the **P** drive is mapped to the Linux directory **/home/public**.

3 Alternatively, you may start the *VMware Workstation* application from the desktop, invoke the **File > Open** menu command, navigate to this same file, and click **Okay**.

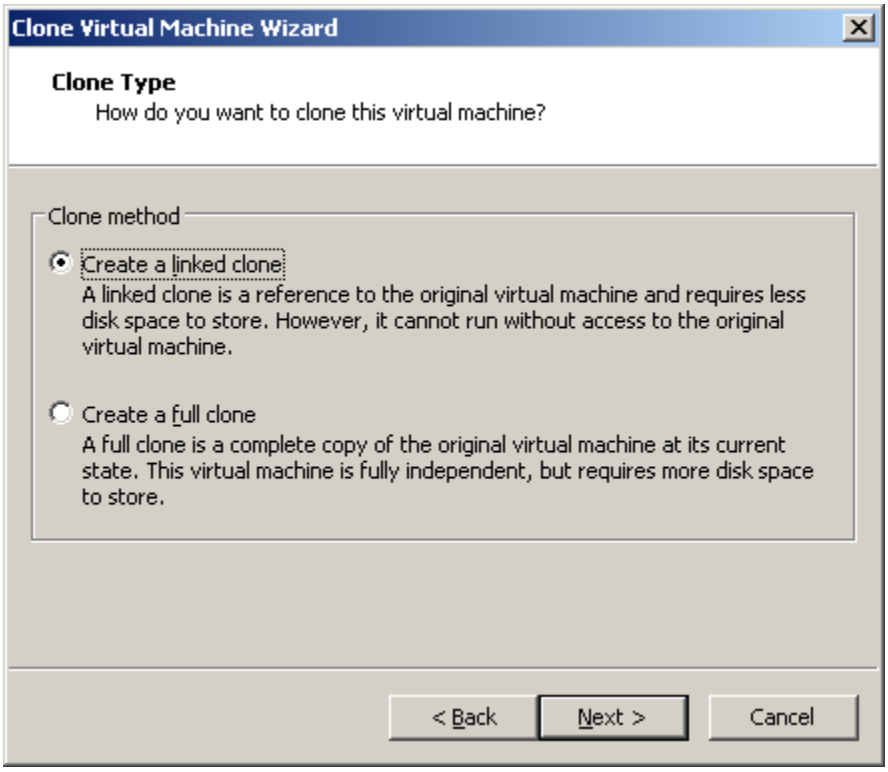

Figure 2

For now, it is recommended that you create a *linked clone* — i.e. a clone in which only the disk blocks that are different from the master are replicated. The disks blocks that are still the same as the master point back to the master. This saves space on the Fossil server. If you store the linked clone on your desktop, it will follow you to any PC in the Fossil Lab.[4]

Select **`Create a Linked Clone`** and click **`Next`**. This takes you to another window in which you can name your virtual machine and assign a location to store it. It suggested that you store your virtual machine in a folder on your desktop or **`H`** drive, so that it is accessible no matter which Fossil workstation you use. Although the files of the virtual machine are stored on the server, they are cached[5] on the local hard drive of the Fossil PC, so there is little performance penalty.

After you click **`Next`**, *VMware* will create a linked copy of the virtual machine in the directory or folder that you specified, and then it will return you to the *VMware Workstation* main window as shown in Figure 1. You will notice that a new tab representing the cloned machine has been added to that window.

If you were to list the folder where you stored your virtual machine, you would find something resembling the following:–

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4 Creating a *full clone* is equivalent to installing your virtual machine from DVD, as described below.

5 We will study *caches* extensively in this course, especially the performance characteristics of caches.

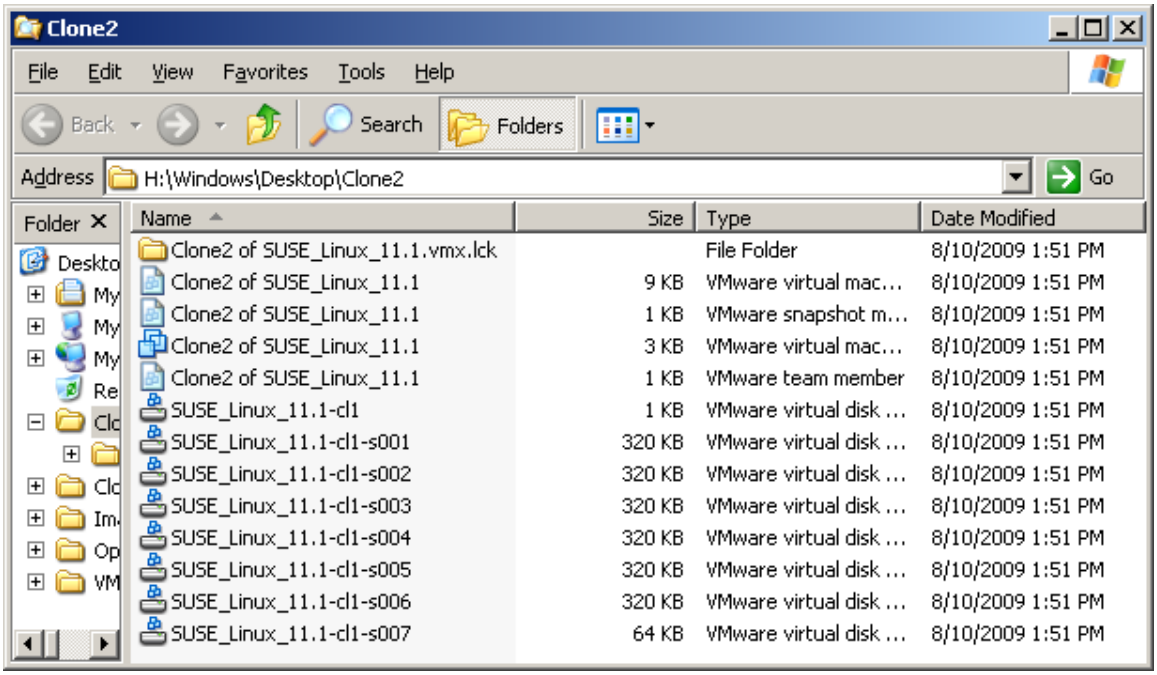

Figure 3

The *VMware virtual disk* files with names like **`SUSE_Linux_11.1-cl1-s001.vmdk`** are clones of the files with corresponding names in the master virtual machine. These implement the disks of your virtual machine. You will notice that they are quite small right now, even though the combined storage of the master virtual machine is over six gigabytes. These files will grow as you modify files in your virtual machine, causing the modifications to be stored in the disk files of the clone.

If it turns out that performance becomes a problem during peak periods just before assignments are due, it is possible to move your virtual machine clone to the hard drive of a Fossil PC. The advantage is that you will not be competing for network and disk bandwidth to write disk blocks of your virtual machine back to the Fossil server. The disadvantage is that you are tied to a particular PC in the Lab. If someone else happens to be using that PC, you will be out of luck.

It is up to the students of the course to share the PCs of the fossil lab so that everyone has an equal opportunity to complete assignments. *If there is a problem with such sharing, the practice of allowing virtual machines to be stored on the hard drives of Fossil Lab PCs will be outlawed.*

Installing your virtual machine from DVD

Corporate and graduate students — and undergraduate students who do not plan to use the Fossil Lab — will need to install their virtual machines on their own laptop or desktop computers or corporate *VMware* servers. The virtual machine is contained in a zipped folder of files. It will be distributed by DVD in graduate classes; and it may be obtained from the Fossil server by undergraduate students at

`/home/public/CS-3013/A-term_2009/SUSE_Linux_11.1(CS-3013).zip`

or from any Fossil Lab workstation at

`P:\CS-3013\A-term_2009\SUSE_Linux_11.1(CS-3013).zip`

Unzip this folder into a suitable place on your hard drive. Please remember that the unzipped files will eventually grow to about 15 gigabytes as you use your virtual machine. The unzipped folder should look something like this:–

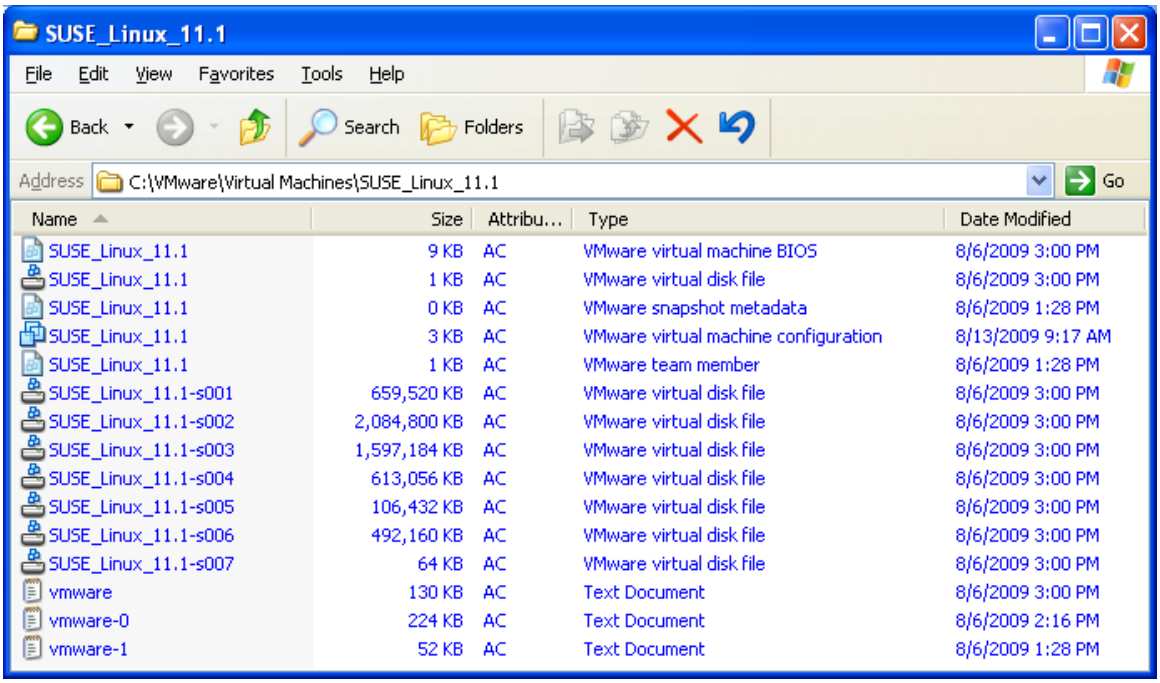

Figure 4

The most important file is the *VMware virtual machine configuration* file, which has the same name as the virtual machine itself. This text file describes all of the attributes of the virtual machine and its component files. Note that in this folder, the virtual hard drive is simulated by a collection of files, each of which can grow to 2 gigabytes. Also note that when the virtual machine is running, several additional files will be created. In addition, a lock folder will be added to prevent the virtual machine from being opened more than once concurrently. None of these are included in the zipped folder, but instead they are created on the fly.

Before you can use your virtual machine, you need to acquire and install *VMware Player* (Windows or Linux), *VMware Workstation* (Windows or Linux), *VMware Fusion* (Macintosh), or the *VMware Client* associated with your *VMware Server*.

You can download and install the free *VMware Player* from here:–

http://www.vmware.com/download/player/

Other *VMware* products can also be found at the *VMware* download site. Most will require you to pay, but evaluation licenses are available for some. If you are using a corporate or institutional *VMware* server, it has to be installed by your system administrator.

Caution: Do not attempt to start your virtual machine in *VMware Player* yet! First, read the next section about adjusting the properties of your virtual machine.

Adjusting the Properties of your Virtual Machine

Several properties of your virtual machine that you may wish to change include:–

- The size of (simulated) RAM memory

- The type of networking — i.e., *bridged* vs. *NAT*
- Shared folders
- The CD/DVD drive

The size of the RAM memory and the type of networking can be changed when the virtual machine is running, but changes do not take effect until it is restarted. Shared folders can be added and deleted, and CDs or DVDs can be inserted, ejected, and/or mapped to image files while the virtual machine is running.

Size of RAM memory

By experience, we have found that the virtual RAM of the guest system should not exceed 50% of the host RAM. Since the Fossil Lab machines have 2 gigabytes of (host) RAM, we set the default size of the virtual RAM of the virtual machine to 1 gigabyte. If you have more RAM on your computer, you may increase this.

In *VMware Player*, you can only change the size of RAM in the guest machine after you have started it. Use the **`VMware Player > Troubleshooting`** menu of Figure 11. Changes will not take effect until the virtual machine is shut down and restarted.

VMware Workstation and all other *VMware* platforms:– open the virtual machine by navigating to and double-clicking on the *VMware virtual machine configuration* file. This file is named **`SUSE_Linux_11.1.vmx`** or whatever name you gave to your virtual machine when you made a clone. Double-clicking will start the *VMware* application and present you with a window like Figure 5 below.

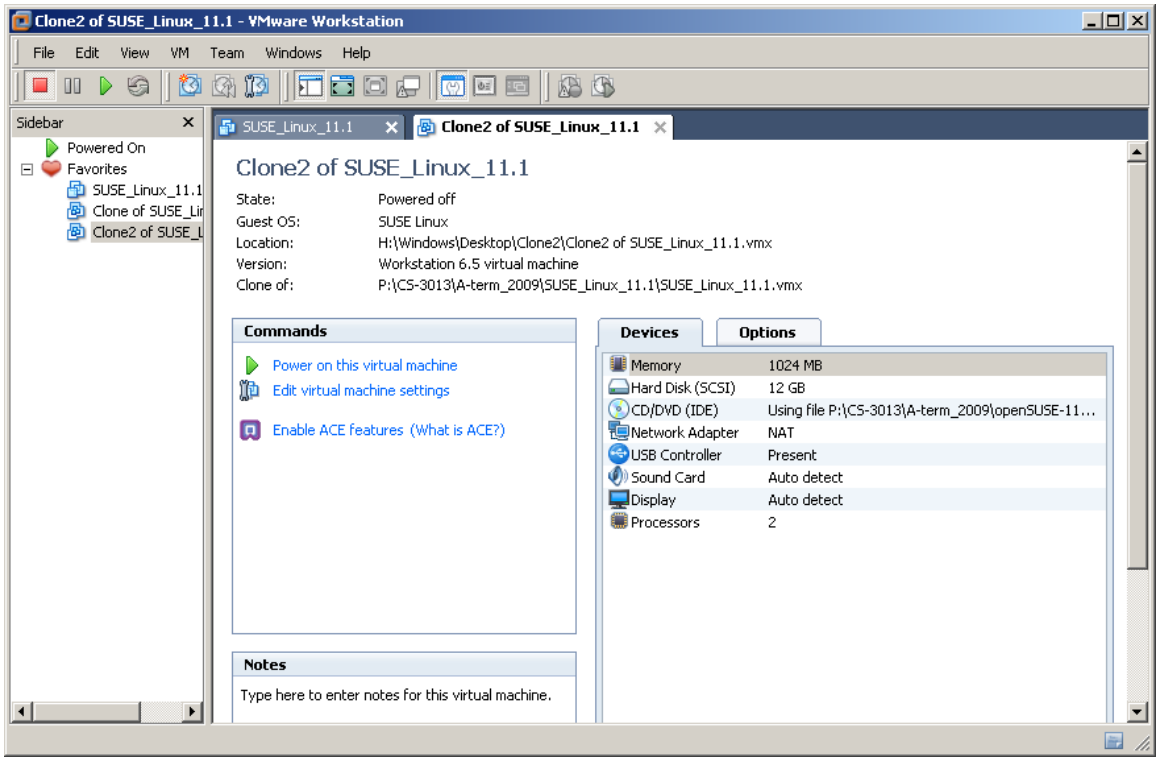

Figure 5

Select the *Devices* tab in the right-hand panel and double-click on the *Memory* line to open the control panel for RAM memory. Adjust the size of the RAM memory in this control panel and click **Okay**. The maximum recommended RAM memory is about half the size of the RAM on your host system.

Bridged vs. *NAT networking*

There are two ways[6] in which your virtual machine can connect to the network:–

- *Bridged* networking means that your virtual machine looks like any other device on the network. It has its own IP address and its own MAC address, separate from the host system. It is completely indistinguishable from a hardware system with the same IP and MAC addresses.
- *NAT* means *Network Address Translation*.[7] It is a technique by which the *VMware* application on your host computer re-addresses every packet from and to your guest operating system so that those packets appear to the outside world as if they come from or go to the host itself. The virtual machine and guest operating system are completely invisible.

Normally, you would use bridged networking only on unsecured networks or networks for which you manage the security yourself — for example, your home network. You must use NAT if your network administration controls, registers, and/or manages all computers and devices attached to it — for example, the wired and wireless networks of the WPI campus or your corporate network.

Your virtual machine as distributed with NAT networking by default. If you wish to change it in *VMware Workstation* or other *VMware* application (but not *VMware Player*), double-click on the *Network Adapter* line of the *Devices* tab of Figure 5 and change it in the control panel for network adapters.

In *VMware Player*, you can change the type of networking after you have started your virtual machine, as described below. Use the Devices menu of Figure 11. Changes do not take effect until after your restart your virtual machine.

Shared Folders

The openSUSE 11.1 operating system comes with *open-vm-tools* installed by default. This is an open source implementation of *VMware Tools*, which have been distributed by *VMware* for many years. *Open-vm-tools* comprise a number of modules, some loaded into the guest operating system kernel and others operating in the guest user space. These make the operation of the virtual machine and guest system more efficient — for example, the virtual display and network cards communicate via a private channel directly with the *VMware* application.

A very useful tool is the *shared folder* — i.e., a folder or directory of the host system that can be read and written by the guest operating system. *You will use this a lot in this course!* In the guest operating system, the shared folder is implemented by a special file system called the *Host-Guest File System,* or *hgfs* for short, which is part of *open-vm-tools.* A directory called

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6 The third option, *host networking*, is used when you want to create a suite of virtual machines on the same host, all connected to each other but isolated from the outside world. We do not use it in this course.

7 NAT is widely used in hubs and gateways for home and small business networks to isolate their IP addresses from those of the Internet.

`/mnt/hgfs`

has been created for you in the guest operating system of your virtual machine. All shared folders appear within this directory as they are added in the host.

By default, sharing between host and guest is disabled whenever your clone or copy a virtual machine. You have to enable it again explicitly for this course.

- In *VMware Player*, you can enable it after you start your virtual machine, as described below. It will remain enabled after you shut down and restart.
- In *VMware Workstation* and other *VMware* applications, you can enable sharing prior to starting your virtual machine. In the right panel of Figure 5, select the *Options* tab and double-click on the *Shared Folders* line. This will bring up Figure 6 below.

  Select the *Always Enabled* button. In the *Folders* panel in the bottom part of this window, you can add and remove folders and change their properties. In particular, you can make them read-only or writable by the guest system.

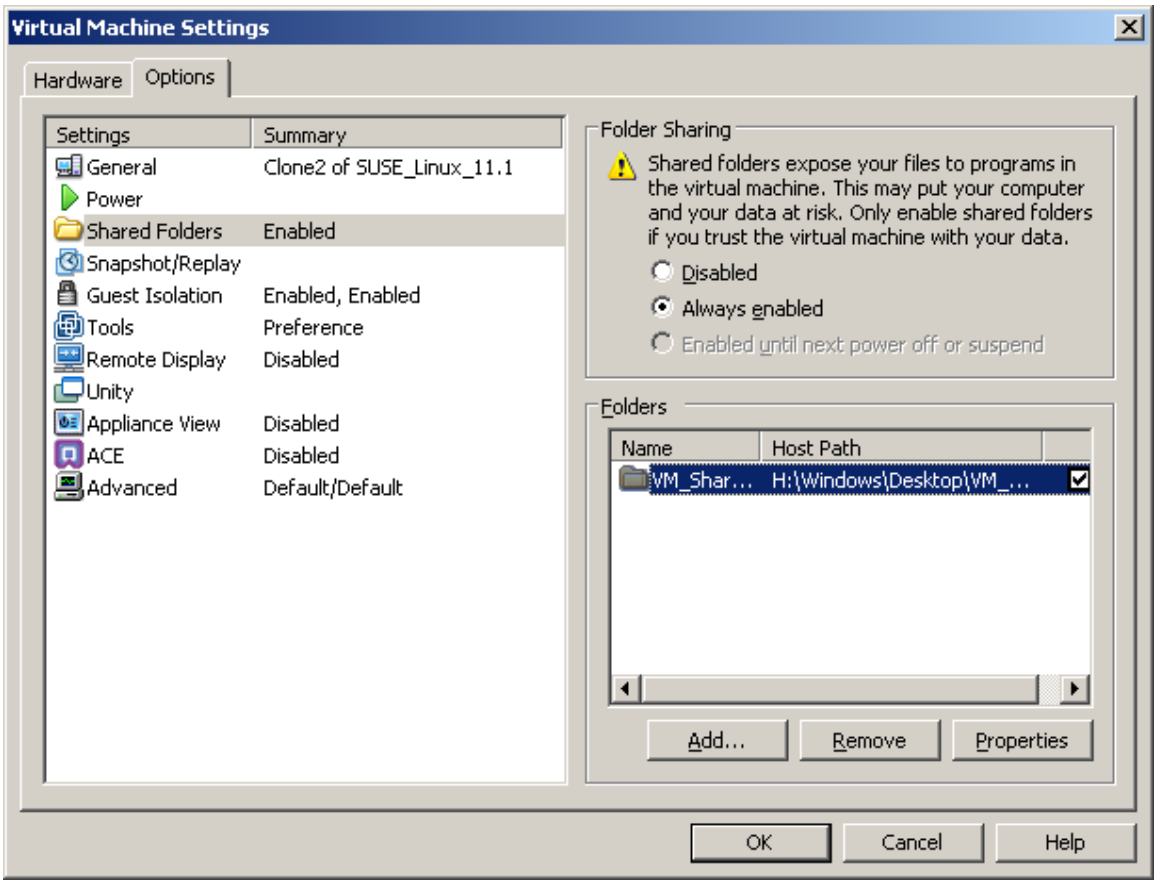

Figure 6

In all versions of *VMware*, you may *enable* and *disable* shared folders at run time. This is equivalent to *mounting* and *unmounting* devices in your virtual machine. That is, if you enable shared folders, the list of folders in the *Folders* panel in the lower right of Figure 6 becomes the list of subdirectories of **`/mnt/hgfs`**. If you disable shared folders, they magically disappear from **`/mnt/hgfs`**. Moreover, you can add or remove individual host folders at run time, and they will magically appear or disappear as individual subdirectories of **`/mnt/hgfs`**.

CD-DVD device

The virtual machine for this course is distributed with a virtual DVD installed in its virtual CD-DVD drive, namely the distribution disk of *openSUSE Linux 11.1*. It is not anticipated that we will need it for this course, and you may safely ignore an error about the CD-DVD drive if you are not working in the Fossil Lab.

At run time, you will able to change the mapping of this drive to disk images (i.e., **`.iso`** files) in the host, to connect this virtual drive to a physical CD-DVD drive in the host, or to disconnect it altogether.

Starting your Virtual Machine for the first time

To start your virtual machine in *VMware Player*, start the *VMware Player* application. You will see the following window:–

Figure 7

Click the *Open* folder in this window and navigate to the *VMware virtual machine configuration* file of your virtual machine. Opening this file automatically starts the virtual machine. In the future, you may simply select your virtual machine from the list under *Recent Virtual Machines*.

If you are using *VMware Workstation* or another *VMware* application, click **`Power on this virtual machine`** in the *Commands* panel of Figure 5.

If you installed from the zipped distribution of the virtual machine, then the next thing you should see is the following dialog box:–

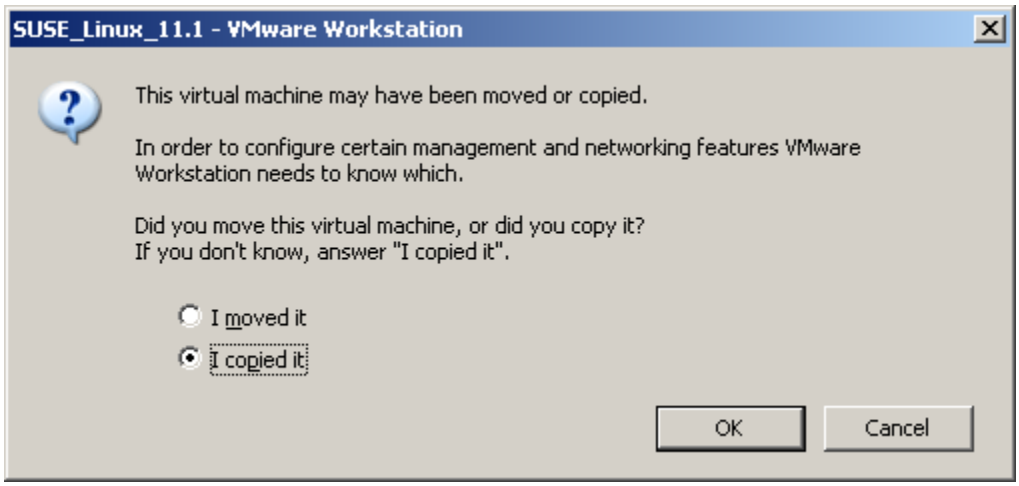

Figure 8

Be sure to select "I copied it." The reason is that *VMware* fabricates a network MAC address from the path name of the *VMware virtual machine configuration* file.[8] *VMware* uses this path name to figure out whether it is dealing with the same virtual machine or a copy. Very, very bad things happen when two or more computers get onto the same network with the same MAC address. By selecting "I copied it," *VMware* changes the MAC address to something different (and hopefully unique, at least within the scope of your network).[9]

Note 1: You won't see this dialog if you cloned your virtual machine from the master in the Fossil Lab, for the simple reason that *VMware* already knows that it is a copy and has already changed the MAC address of its network adapter.

Note 2: Later, when you open your virtual machine on a different Fossil Lab PC from the one where you created it, you may get this message again. This time, select "I moved it" so that it keeps the same MAC address, thereby avoiding the need to reconfigure the network card (see below).

Next, you will see the boot screen of your virtual machine, as shown in Figure 9. In *VMware Player*, this screen will occupy the entire application window. In *VMware Workstation* and other *VMware* applications, it will occupy a panel of the window, or the entire window, depending upon your settings of the application.

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8 *MAC addresses* are the hardware addresses that Ethernet devices use to communicate with each other. *MAC* stands for "Media Access Code".

9 MAC addresses of network adapters are supposed to be globally unique, and each manufacturer (including *VMware*) is assigned a range of MAC addresses for its own products. Nevertheless, it is possible for network devices to masquerade as others by pretending to have MAC addresses other than their own. For example, cable modems do this all the time in (a controlled way).

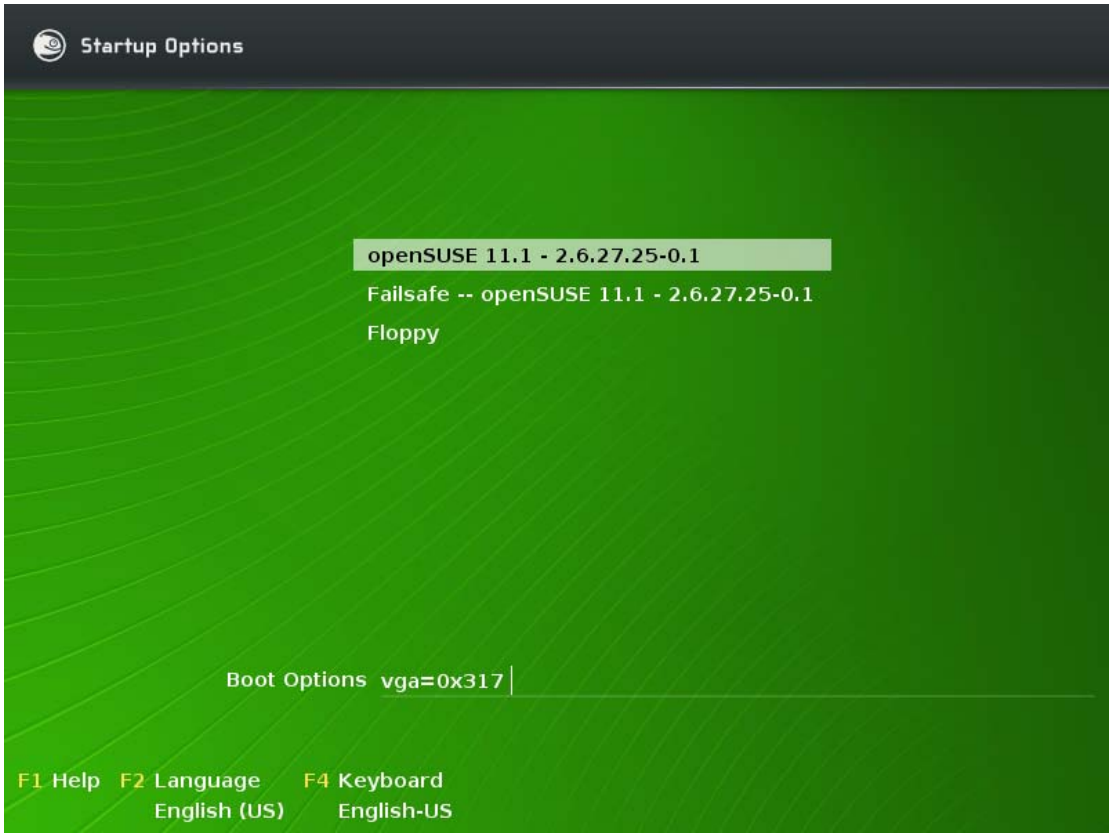

Figure 9

If you do nothing at this point, the virtual machine will boot the default option (**openSUSE 11.1**). The numbers after the operating system identification are the version of the kernel.

In the future, you will need to control the boot options; do this by clicking in boot screen, then using the arrow keys to select the desired option, and finally pressing **Enter**.

Note: You transfer the input focus of the mouse and keyboard to the virtual machine by clicking in its window or typing **CTRL-G**. You can return the input focus to the desktop by typing **CTRL-ALT**. If the input focus is in the wrong place, the virtual machine won't hear you type and won't notice you moving the mouse.

Once the focus is in the virtual machine, you may use the up and down arrows to select the booting option and **Enter** to invoke that booting option. You can also delay the boot process by simply click the arrow keys. This will give you time, for example, to change settings in the *VMware Player* menu bar. There is a settable boot timer that controls how long SUSE Linux waits before booting the default option.

During booting, the screen will briefly change to a text console, and then it will eventually change to a GUI login interface resembling Figure 10. If you want to watch the Linux boot messages, type **ESC** when the input focus is in the virtual machine.

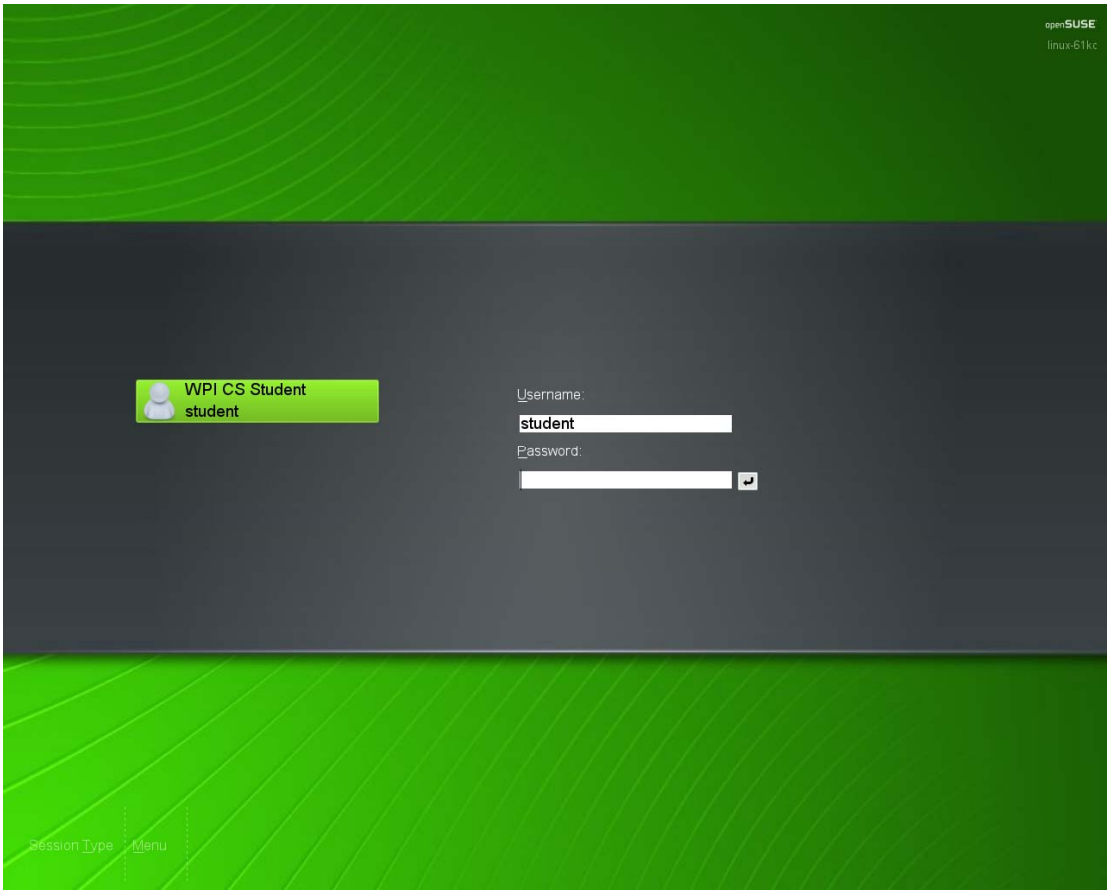

Figure 10

This screen has been configured to be 1280-by-1024 pixels in size, which corresponds to the displays in the Fossil Lab. If you wish it to take over the entire display (i.e., run in *full-screen mode*), press **`CTL-ALT-Enter`**. Later, if you wish to return it to a window of your *VMware Player* or *VMware Workstation*, press **`CTL-ALT-Enter`** again.

If the screen in Figure 10 is too large to fit into the *VMware Player* or *VMware Workstation* window, or if it is too large to fit on your monitor in full screen mode, you will see scroll-bars. You may resize the virtual display to fit your own monitor or window later, after you have logged in (see below under *Changing the Display Size*).

When you are running your virtual machine in full-screen mode, a fragment of a menu bar appears at the top of the screen. This lets you access useful *VMware* commands at run time. For example, Figure 11 shows the menu bar for *VMware Player*. The "thumb tack" at the left of the menu bar locks it in place or allows it to retract upward from view. Figure 12 shows the corresponding menu bar from *VMware Workstation*

Figure 11

Figure 12

In the *VMware Player* menu bar, the **`VMware Player`** pull-down menu contains the **`Troubleshoot`** command, which allows the RAM memory size of the guest system to be

changed. It also includes the **Shared Folders** command for enabling or disabling sharing of host folders. The **Devices** pull-down menu includes the commands for changing the type of networking, controlling the CD-DVD drive, and managing USB ports (see below). In the *VMware Workstation* menu bar, the **VM** menu replicates the **VM** menu of the *VMware Workstation* application, including the **Settings…** command, which brings up the equivalent of Figure 5.

At the right of both menu bars are buttons to minimize, maximize, and close the guest.

Logging in

Your login ID is **student**. Yyour password is **CS-3013** or **CS-502**, depending upon which course you are in. After you have logged in, you will be presented with a graphic desktop called *KDE*, the Linux Desktop Environment, shown below. 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.

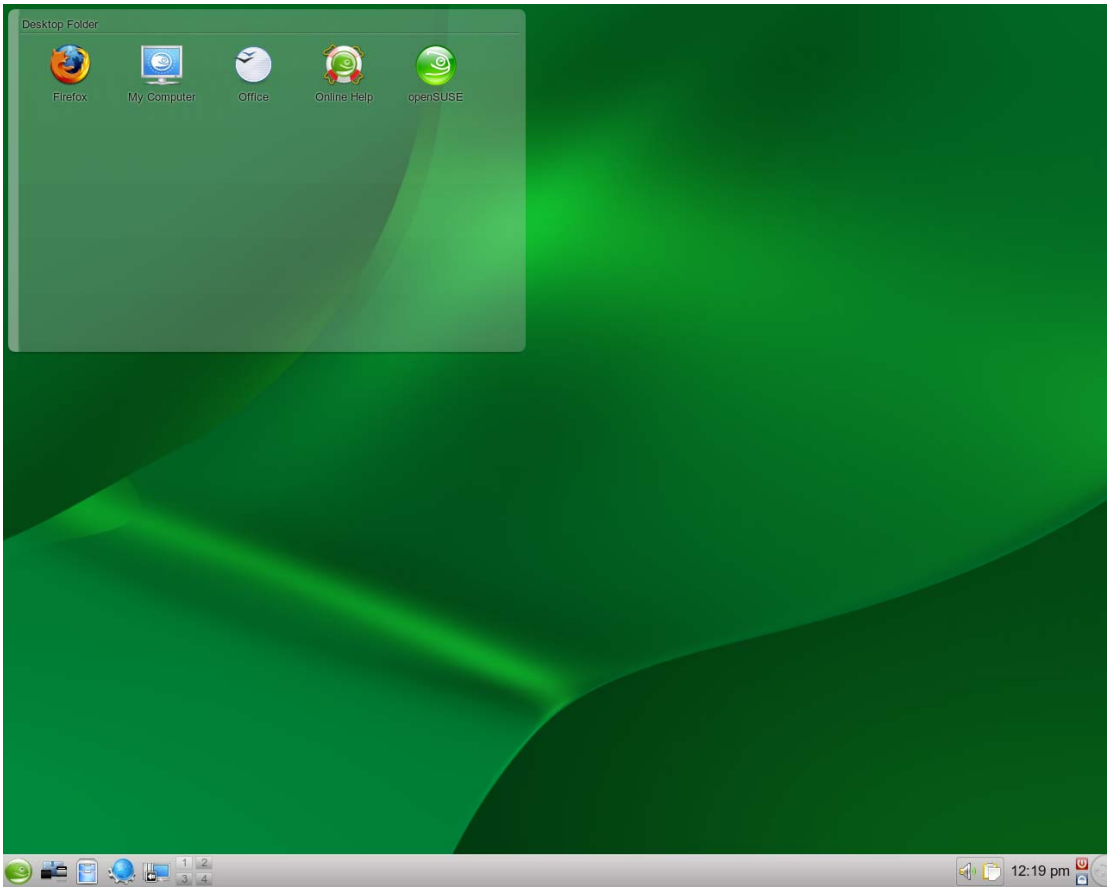

Figure 13

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 reminder, *KDE* configures the user **root** with a red desktop background that contains warning signs and images of bombs.

Note: After you have logged in, o*pen-vm-tools* will be automatically enabled. Then, the input focus will usually follow the mouse. That is, you can move the mouse out of the virtual machine and click in a normal desktop window and work there. You can then move the mouse back into the virtual machine, click, and work there.

Fixing your network connection

An idiosyncrasy of *openSUSE Linux* is that it records the MAC address of its network adapters in an internal configuration file somewhere, and then it looks for a device with that particular MAC address at boot time. The unfortunate consequence is that when the MAC address changed as a result of cloning or copying the virtual machine, the *openSUSE Linux* kernel cannot start the network adapter that it was looking for. To be safe, it does not start the network until you take some action.

To remedy this situation, invoke **YaST**, the system administration tool, [10] to configure the network adapter for the new MAC address. Click the "Gecko" in the lower left corner and select the third submenu, labeled *Computer* and shown below, and select the **YaST** command.

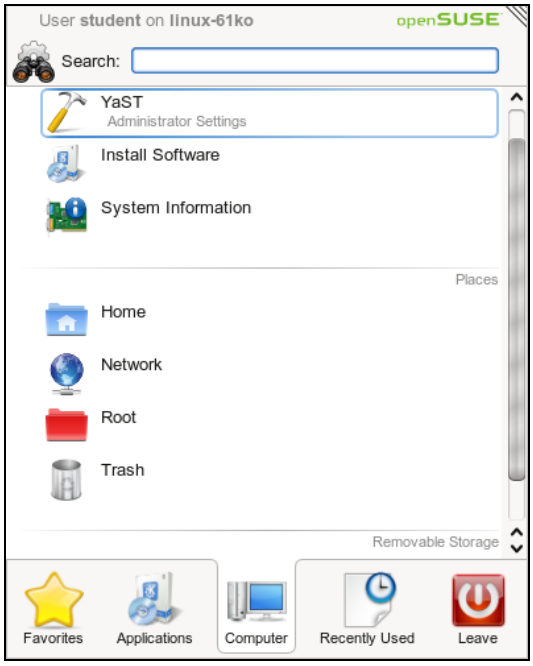

Figure 14

YaST will first ask you for the root password. This is **CS-3013** or **CS-502**, the same as the password for the user named **student**. It will then bring up the **YaST** window, shown in Figure 15. Select **Network Devices** in the left panel, and then select **Network Settings** in the right panel. This will bring up the windows of Figure 16

[10] So far as I can tell, YaST stands for *Y*et *a*nother *S*ystem *T*ool.

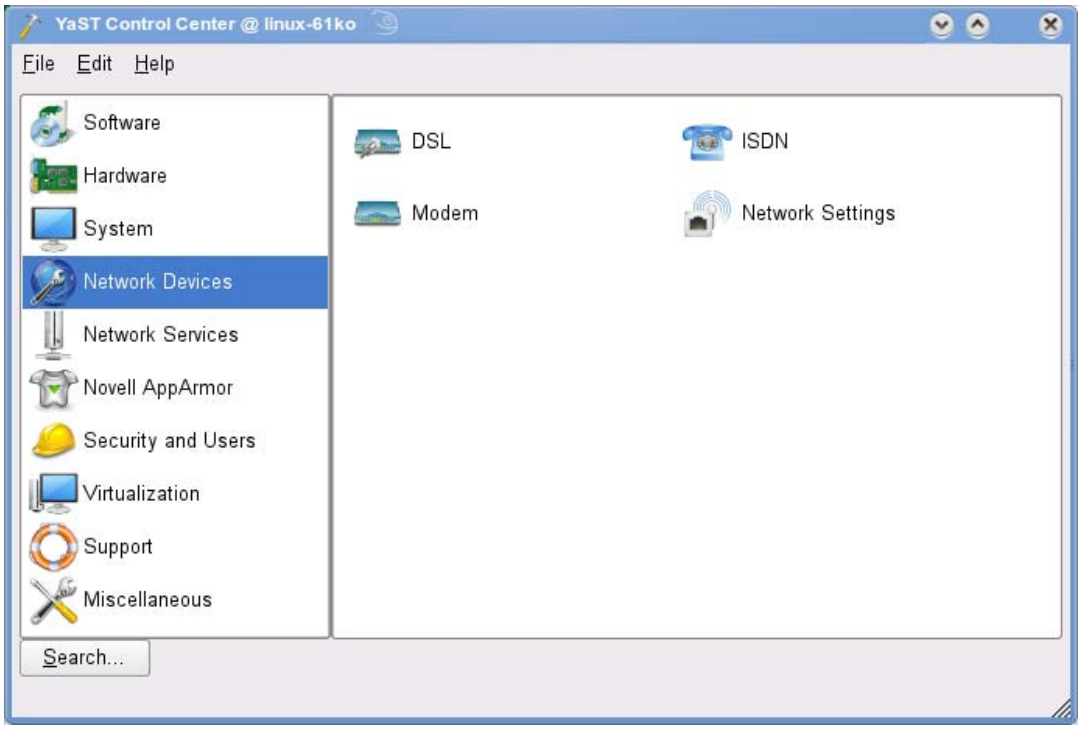

Figure 15

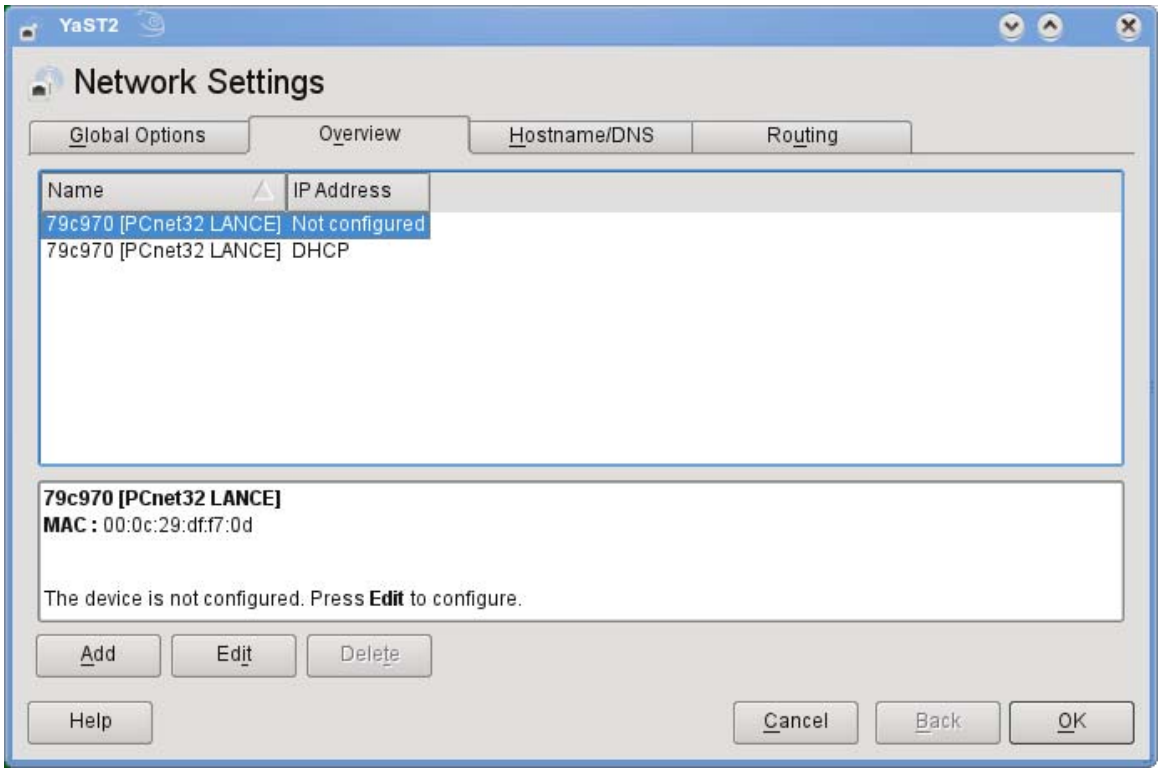

Figure 16

Select the device that is "Not configured" and click **`Edit`**. In the next window, accept the proposed settings and click **`Next`**. The **`Network Settings`** tool should reconfigure its

devices and exit. You can test your network connection by opening a network browser or by executing the following command in a command shell:–

```
/sbin/ip address
```

If it displays an IP address, you have successfully configured the network.

A command shell can be opened by clicking on the Gecko button and selecting the **Terminal** application near the bottom of the **Favorites** tab or by selecting the **Applications** tab and **System** submenu, where the **Terminal** application can also be found.

Creating a user identity for yourself

It is helpful to create a user identity for yourself and to get rid of the **student** identity built into these virtual machines. If you are part of a team, create an identity for each team member. To create a user identity, open **YaST** again and this time 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. 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, you need to do it in two places — **YaST** and *KDE*. First, open **YaST**, select *Hardware* in the left panel and *Graphic Card and Monitor* in the right panel. This brings up the *Monitor Properties* panel, shown in Figure 17.

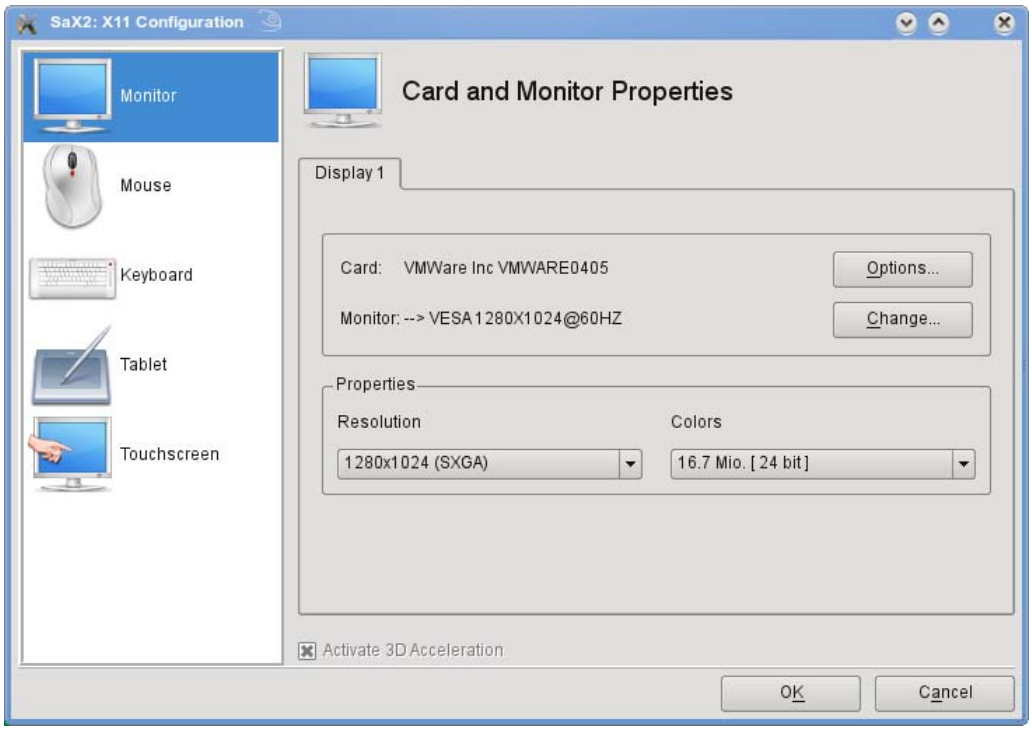

Figure 17

In this panel, change the *Monitor* to a type with the resolution of your display — for example, *VESA 1024×768@60 Hz* — and then set the resolution below to match. Clicking **OK** will test the monitor before committing the changes. It seems that you have to restart your system before the changes actually take effect.

After restarting, invoke the **Configure Desktop** command from the Gecko menu. This brings up the following window

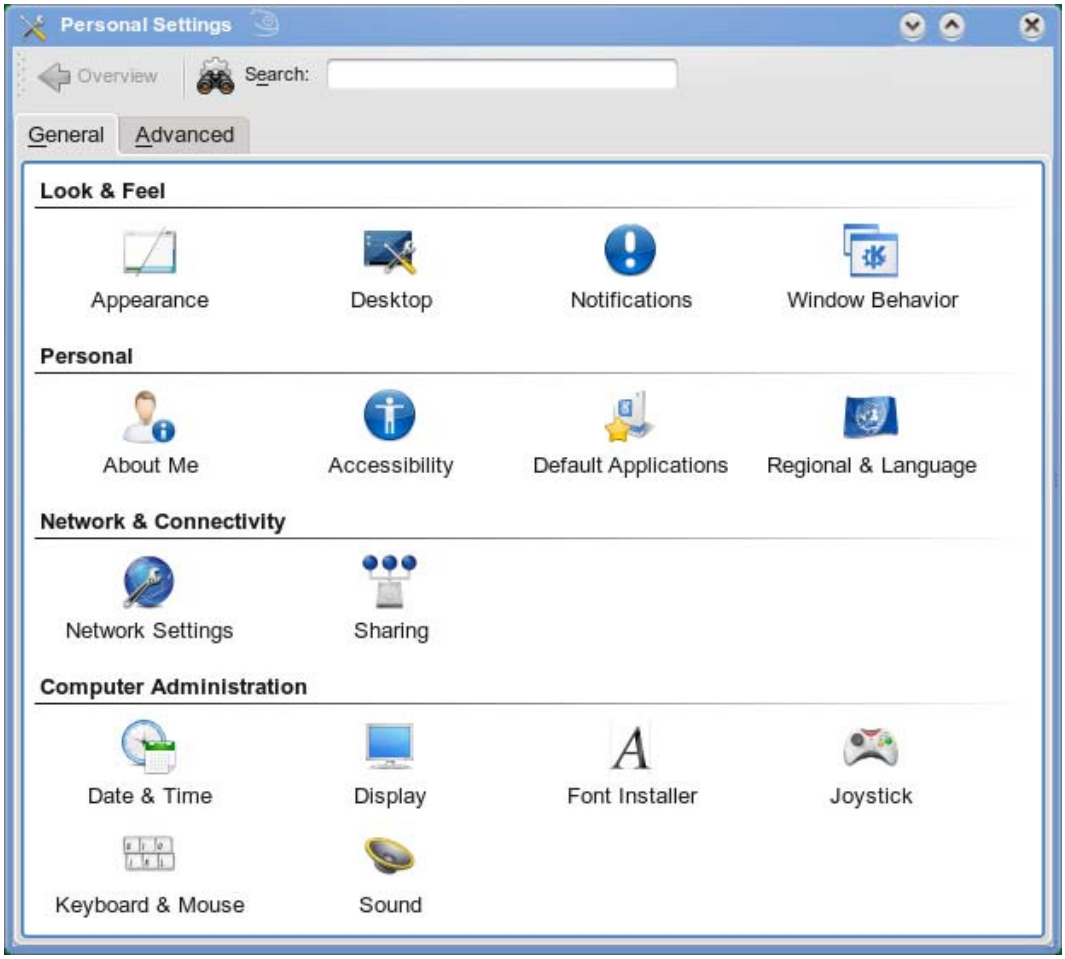

Figure 18

Select *Display* in the bottom section to tell *KDE* the size of the display, which should correspond to what you told **YaST**. Finally, select *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. Note especially the *Force Fonts DPI* pull-down menu near the bottom, which controls the number of pixels per inch. Setting this will help the font sizes that you choose to look like those sizes on the virtual display.

Useful Features

You are now in a position to experiment with and explore your very own Linux system. You don't have to use the Graphic User Interface, but it saves a lot of time and a long learning curve. You are also in a position to experiment with useful tools of *VMware*. This section discusses several of them.

Snapshots

A highly useful feature of *VMware Workstation* is the ability to take snapshots. This is accessed from the *VM* menu of the *Workstation* application (and also the menu bar at the top of the full-screen mode display). When you take a snapshot, *VMware* records the state of your virtual machine for future use. Later, after you have crashed or corrupted your disk beyond belief, you can restore it to a previous state by invoking the *Snapshot* command in the *VM* menu.

To make a snapshot, *VMware* uses the same mechanism that it uses to make clones. That is, a record of all of the disk blocks is made, and any subsequent changes to any disk blocks are made to new copies. Later, to revert to a snapshot, the new copies of blocks are discarded and the original blocks are restored. Conversely, if a snapshot is deleted, the copied blocks and original blocks are merged so that the appropriate state is preserved. *VMware* does this automatically for you, so you don't have to keep track of it yourself.

It is possible to have snapshots of snapshots, recursively, but it is not advisable because performance can suffer.

Unfortunately, snapshots are *not* available in *VMware Player*, and they only have limited capability in some other *VMware* products.

Suspending, Restarting, and Moving your Virtual Machine

Another highly useful feature of *VMware* is that you can suspend a virtual machine and resume it later. Simply use the *Suspend* sub-command of the *Power* command of the *VM* menu. Moreover, you can log out, leave the Fossil Lab, return later, log into a *different* Fossil workstation, and resume your suspended virtual machine.

When you do resume it, you may get a dialog box saying that it noticed that your machine is in a different place than before and asking if you copied or moved it. Respond to this dialog saying that you *moved it*, so that *VMware* does not gratuitously change the MAC address.

Shared Folders

Shared folders were discussed above. These are a very useful way of transferring files between host and guest — something that you will need to do often. For example, if you have files you want to save before you try out something potentially dangerous, copy them into a shared folder and the disable that particular folder. This way, the files will be protected in the host and will be safe, even if you crash the guest operating system, corrupt its disk, etc.

The one caveat is that shared folders are part of *open-vm-tools*, and *open-vm-tools* are tied to a particular version of the Linux kernel. If you modify and rebuild the kernel, the tools do not work with the modified kernel. Fortunately, they will resume working when you reboot the original kernel.[11]

USB flash drives

Your virtual machine and *openSUSE Linux* support the usual assortment of flash drives. If you plug in a USB device while the input focus is in the guest operating system, it usually

[11] This is a welcome change from previous terms, where we had to use the proprietary *VMware Tools*. In that case, the shared folders stopped working and would not work again without being recompiled.

opens in the guest. You can access the device from the *KDE* desktop by clicking on the **Device Notifier** button, which is four buttons to the right of the **Gecko** button

Sometimes, however, *VMware* gets into the act and brings up a dialog box asking whether you want to connect the device to the host or the guest. Answer the dialog appropriately. Also, if you particularly do not want a device connected to the guest, go to the **Devices** menu in the *VMware Player* menu bar or the **Removable Devices** command of the **VM** menu in *VMware Workstation* and manage the device there.

Fortunately, USB devices work in modified kernels, provided that the drivers have not been deleted.

Disaster Prevention

During the first several terms when we taught Operating Systems courses using *VMware* virtual machines, students stumbled on a number of idiosyncrasies that rendered their virtual machines totally inoperable, trapping all of 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 is to copy the relevant files onto a USB flash drive or a shared folder. From time to time, we have tried other methods of protecting students from lost work — particularly, configuring virtual machines with separate drives for the **/home** directory — but none of them has proven very practical.

Conclusion

That's it. Enjoy your virtual machine. You are now ready for your first kernel project. When you are ready to take a break, you may power off your virtual machine by invoking the "leave" tab from the Gecko menu and selecting the appropriate option. You may also "Suspend" the virtual machine by simply exiting *VMware Workstation*.

Documentation

Documentation for *VMware Workstation* can be found here:–

http://www.vmware.com/support/pubs/

Documentation about OpenSUSE Linux can also be found on-line at

http://en.opensuse.org/Documentation

and

http://www.novell.com/documentation/opensuse111/

This includes a getting started guide, a user's manual, an administrator's manual, and other information. Do not try to print these. Together, they are well over 1000 pages.