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**Research Findings**

**for Lustre Distributed File System**

**Graduate Research Project**

Sponsor

**The Department of Electrical, Computer, Software & Systems Engineering at**

**Embry-Riddle Aeronautical University**

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**Abstract:** Lorem ipsum dolor sit amet, consectetur adipiscing elit. Aenean sit amet dolor turpis. Nam posuere lorem nibh, nec posuere lorem ultrices et. Proin est diam, volutpat nec leo ac, congue ultricies odio. Fusce turpis sapien, porta sed nunc eget, interdum dictum odio. Vestibulum id est id lacus feugiat dictum. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Donec viverra augue orci, ac posuere elit interdum id. Vestibulum justo orci, suscipit non elit sed, placerat consectetur mi. Vivamus et odio ullamcorper, semper lorem nec, auctor urna. Proin risus nisi, ullamcorper a varius eget, elementum vel lorem. Maecenas justo ligula, dignissim et diam et, rhoncus lobortis erat. Nam molestie lorem ac mauris blandit eleifend. Nunc gravida sodales nisl, sed eleifend ante dapibus vitae. Duis convallis quam sit amet rutrum placerat. Aenean blandit in elit eu luctus. Maecenas nec tortor vitae leo rhoncus placerat.

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# Revision History

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# Introduction

# Background

# Installation Procedures

This section contains the installation instructions used to create the Virtual Machine (VM) image used to install the Lustre server and client software. While [1] describes the installation procedures for Lustre, this source does not describe the process through which the VMs for the Lustre file system are created. Therefore, the following walkthrough describes the installation and configuration process, from start to finish, for both creating the VMs as well as installing the Lustre software. For more detailed information on how to install the Lustre software and create a Lustre cluster, see **Part II: Installing and Configuring Lustre** of [1].

Section 1 describes the process used to install the Lustre server software on a VM and configure the VM to act as a server node in a Lustre cluster. Section 2 describes the procedures required to configure a series of Lustre server VMs, as created in section 1, to act as the server-side nodes (MGS, MDS, and OSSs) in a Lustre cluster. Section 3 describes the installation procedures for installing and configuring a VM to act as a client in a Lustre cluster. Section 4 describes the configuration procedures required to connect the client or clients created in section 3 to the Lustre cluster created in section 1 and 2.

Note that each of these sections contain information on any issues encountered during the procedures. Likewise, at the time of writing, the server-side portion of the Lustre cluster (MGS, MDS, and OSSs) could not be successfully connect to one another. Therefore, the sections pertaining to this shortfall contain detailed description of the errors encountered and information relating to possible solutions and the solution approach taken thus far to mitigate or solve any of these issues.

## Lustre Server Installation & Configuration Procedures

This section contains the detailed procedures for creating a base server VM used to create the MGS, MDS, and OSSs in the Lustre cluster. This section includes information on how to create the VM image for the MGS, MDS, and OSSs, as well as how to configure this image to be included in a Lustre cluster (the scope of this configuration stops at network configuration; subsequent sections cover the configuration required to create a MGS, MDS, or OSS from this base-image).

### Creating Virtual Machine Image

The VM used to run the Lustre software was created and executing using VMWare Player 7[[1]](#footnote-1) using the auto-installer for CentOS 6.6[[2]](#footnote-2) 64-bit. In order to create the VM for CentOS 6.6, complete the following steps:

1. Open VMWare Player
2. Under the **Welcome to VMWare Player** heading, press the **Create a New Virtual Machine**
3. In the **New Virtual Machine Wizard** window, select the **Installer disc image (iso)** option
4. Select the **Browse** button and select the International Organization for Standardization (ISO) file representing the CentOS 6.6 installation image
5. Press the **Next** button
6. Enter the personalized information for the CentOS installation, such as the full name of the user, the login username, and the password for the login user
7. Press the **Next** button
8. Enter the **Virtual Machine name**, which will displayed in the list of VMs in VMWare Player
9. Select a location to store the VM files on the local machine
10. Press the **Next** button
11. Select a **Maximum disk size**
12. Select the **Split disk into multiple files** option
13. Press the **Next** button
14. Ensure that the **Power on this virtual machine after creation** option is checked
15. Press the **Finish** button

VMWare Player will then execute the auto-installer for CentOS 6.6, installing a Graphical User Interface (GUI) for CentOS. While this GUI is not required, some of the tools needed, such as Wireshark, are arguably easier to use with a GUI, and therefore, a GUI for CentOS is installed. The auto-installer will take a few minutes to install the operating system; once this installation is completed, CentOS will automatically boot. When presented with the CentOS login screen, enter the login username and password specified in step (6) above. Once logged into the CentOS VM, the Lustre software and supporting tools can be installed.

### Installing Lustre Software

Throughout the following steps, it is assumed that CentOS VM is configured to use a Network Address Translation (NAT) network configuration. In order to change the network configuration for the VM,

1. Select the **Player** dropdown at the top-left of the VMWare window executing the CentOS VM
2. Select the **Manage** option
3. Select the **Virtual Machine Settings…** option
4. Select the **Network Adapter** option under the **Hardware** tab
5. Change the network configuration options under the **Network Configuration** heading on the right
6. Press the **OK** button once the desire configuration is set

In order to install the software required to run the Lustre file system, a shared directory is used and mounted in the CentOS VM, thus allowing the needed RedHat Package Management (RPM) files to be transferred to and installed on the CentOS VM. To create the shared directory,

1. Select the **Player** dropdown at the top-left of the VMWare window executing the CentOS VM
2. Select the **Manage** option
3. Select the **Virtual Machine Settings…** option
4. Select the **Options** tab (next to the **Hardware** tab used when configuring the VM network)
5. Select the **Shared Folders** option on the left column
6. Check the **Always Enabled** option under the **Folder sharing** section in the right column
7. Press the **Add…** button at the bottom of the **Folders** section below the **Folder sharing** section
8. Press the **Next** button
9. Press the **Browse…** button under the **Host path** section
10. Select the directory to be shared between the host machine and the CentOS VM
11. Change the name of the shared directory, if desired, under the **Name** section (the name of this directory will be referenced as <shared\_dir> for the remainder of the installation procedures)
12. Press the **Next** button
13. Ensure that the **Enable this share** checkbox is checked under the **Additional attributes** section
14. Press the **Finish** button

To verify that the shared directory has been properly mounted in the CentOS VM, open a shell in the VM and execute the following command,

|  |  |
| --- | --- |
| $ | ls -l /mnt/hgfs/<shared\_dir> |

where <shared\_dir> is the name of the directory selected in step (11) when creating the shared directory. Once the shared directory has been established, the needed packages can be moved into this directory and installed. In order to install the Lustre file system on the CentOS VM, the following packages are required:

* kernel-2.6.32-431.20.3.el6\_lustre.x86\_64.rpm
* lustre-2.6.0-2.6.32\_431.20.3.el6\_lustre.x86\_64.x86\_64.rpm
* lustre-iokit-2.6.0-2.6.32\_431.20.3.el6\_lustre.x86\_64.x86\_64.rpm
* lustre-modules-2.6.0-2.6.32\_431.20.3.el6\_lustre.x86\_64.x86\_64.rpm
* lustre-osd-ldiskfs-2.6.0-2.6.32\_431.20.3.el6\_lustre.x86\_64.x86\_64.rpm
* lustre-tests-2.6.0-2.6.32\_431.20.3.el6\_lustre.x86\_64.x86\_64.rpm
* libcom\_err-1.42.12.wc1-7.el6.x86\_64.rpm
* libss-1.42.12.wc1-7.el6.x86\_64.rpm
* e2fsprogs-1.42.12.wc1-7.el6.x86\_64.rpm
* e2fsprogs-libs-1.42.12.wc1-7.el6.x86\_64.rpm
* compat-openmpi-1.4.3-1.2.el6.x86\_64.rpm
* environment-modules-3.2.10-1.el6\_5.x86\_64.rpm
* libesmtp-1.0.4-15.el6.x86\_64.rpm
* libgfortran-4.4.7-11.el6.x86\_64.rpm
* libgssglue-0.1-11.el6.x86\_64.rpm
* libibverbs-1.1.8-3.el6.x86\_64.rpm
* librdmacm-1.0.18.1-1.el6.x86\_64.rpm
* plpa-libs-1.3.2-2.1.el6.x86\_64.rpm
* sg3\_utils-1.28-6.el6.x86\_64.rpm
* tcl-8.5.7-6.el6.x86\_64.rpm

While not all of the files listed above are required directly for a Lustre installation, this list includes all dependencies of the core Lustre packages, as well, allowing a user to install the complete Lustre file system server files without the need for an internet connection (which may not be present in the environment of the VM). Each of these files can be downloaded directly from https://github.com/albanoj2/grp/tree/master/lustre-packages/server. Apart from the core Lustre server files, the following RPMs should also be installed:

* wireshark-gnome-1.8.10-7.el6\_5.x86\_64.rpm

This package provides the Wireshark application, and its associated GUI. This application will be used to analyze the network traffic originating from the Lustre file system. The non-core packages can likewise be found at https://github.com/albanoj2/grp/tree/master/lustre-packages/tools.

To install these packages, login as the root user using the following command:

|  |  |
| --- | --- |
| $ | su |

When prompted, enter the login password selected during the creation of the CentOS VM (the default root password is the login password selected during the creation of the CentOS VM). Once logged in as the root user, change directory to the shared directory containing the RPMs to be installed and execute the following command:

|  |  |
| --- | --- |
| # | yum --nogpgcheck install \* |

This command assumes that all of the packages to be installed (both the core Luster server packages, as well as the non-core packages) reside in the same directory. If this is not the same, simply change directory to any directory containing packages to be installed and execute the following command:

|  |  |
| --- | --- |
| # | yum --nogpgcheck install <rpm\_1> <rpm\_2> ... <rpm\_n> |

where <rpm\_1>, <rpm\_2>, etc. are the names of the RPMs to install, including the .rpm file extension. The

--nogpgcheck flag disables the GNU Privacy Guard (GPG) check, which allows unsigned packages to be installed (note that the authenticity of unsigned packages cannot be determined). While this is not a suggested practice when downloading packages from unknown or unsafe locations (such as from an unknown repository), the authenticity of these files is known *a priori*, since they were obtained from the official Lustre repository at [2] and [3].

Upon executing this command, the installation process with begin. When prompted to confirm the installation of the packages, enter y. The installation may take a few minutes. Once the installation is complete, a restart is required for the installation of the Lustre kernel to complete (the Lustre kernel will not be loaded until the CentOS VM is restarted). Therefore, reboot the system using the following command as the root user:

|  |  |
| --- | --- |
| # | reboot |

Although logging in as the root user is required to install packages, changing user to the root user using the su command is not always advised. Instead, the user created during the creation process for the CentOS VM can be given sudo rights. Once given sudo rights, this user will no longer be required to switch to the root user. Instead, the user can simply prepend the sudo command to each of the commands requiring root access. For example, sudo echo “Hello, world!” For more information on granting sudo rights to a user, see [4]. The remainder of these installation procedures will assume that user executing commands has sudo rights and therefore, the su command will not be used to switch to the root user.

Once the system has restarted, login to the CentOS VM. To ensure that the Lustre kernel has properly installed, open a terminal and execute the following command:

|  |  |
| --- | --- |
| $ | uname -r |

This prints the release name of the kernel used on the system. After the previous reboot, the CentOS VM should have loaded the Lustre kernel previously installed. Therefore, the output from this command should be

|  |
| --- |
| 2.6.32-431.20.3.el6\_lustre.x86\_64 |

Once the Lustre kernel installation has been confirmed, the CentOS VM can be configured.

### Configuring the Server VM

The configuration of the CentOS VM can be divided into two main parts: (1) configuring Security-Enhanced Linux (SELinux) and (2) configuring the VM hostname and Internet Protocol (IP) address. In order for Lustre to run on a Linux machine, SELinux must be disabled. In order to do this, open the /etc/selinux/config file and change the line

|  |
| --- |
| SELINUX=enforcing |

to

|  |
| --- |
| SELINUX=disabled |

For this change to take effect, the system must be rebooted. However, before rebooting, the hostname can also be changed (saving time by only rebooting the system once, after the hostname has been configured).[[3]](#footnote-3)

In order to configure the hostname, the IP address of the system must be made static. To obtain the current IP address used by the CentOS VM, execute the ifconfig command. This command should return output similar to the following:

|  |
| --- |
| eth0 Link encap:Ethernet HWaddr <some\_mac\_address>  inet addr:192.168.aaa.bbb Bcast:192.168.aaa.255 Mask:255.255.255.0  inet6 addr: fe80::20c:29ff:fe6e:ef4a/64 Scope:Link  UP BROADCAST RUNNING MULTICAST MTU:1500 Metric:1  RX packets:73 errors:0 dropped:0 overruns:0 frame:0  TX packets:51 errors:0 dropped:0 overruns:0 carrier:0  collisions:0 txqueuelen:1000  RX bytes:20412 (19.9 KiB) TX bytes:4570 (4.4 KiB)  lo Link encap:Local Loopback  inet addr:127.0.0.1 Mask:255.0.0.0  inet6 addr: ::1/128 Scope:Host  UP LOOPBACK RUNNING MTU:16436 Metric:1  RX packets:8 errors:0 dropped:0 overruns:0 frame:0  TX packets:8 errors:0 dropped:0 overruns:0 carrier:0  collisions:0 txqueuelen:0  RX bytes:480 (480.0 b) TX bytes:480 (480.0 b) |

Under the eth0 section, the IPv4 address can be found under inet addr:. In the case of this example output, the IPv4 address is 192.168.aaa.bbb. Using this existing address, a static address can be selected from range 192.168.aaa. In the case of this example, the static IP address 192.168.aaa.140 is chosen (this IP address will be referenced by <chosen\_ip> for the remainder of this installation procedure). To set this static IP address, open the /etc/sysconfig/network-scripts/ifcfg-eth0 file in a text editor and perform the following actions:

1. Comment out the line containing UUID=”<some\_uuid4>” by placing a # at the beginning of the line (i.e., change the line to #UUID=”<some\_uuid4>”)
2. Change the line BOOTPROTO="dhcp" to BOOTPROTO="static"
3. Add the line IPADDR=”<chosen\_ip>” (replacing <chosen\_ip> with the IP address selected in the previous paragraph, not literally <chosen\_ip>)
4. Add the line NETMASK=”255.255.255.0” (using the literal value 255.255.255.0)

Save the file. The resulting configuration should resemble the following:

|  |
| --- |
| DEVICE="eth0"  BOOTPROTO="static"  IPADDR="<chosen\_ip>"  NETMASK="255.255.255.0"  HWADDR="<some\_mac\_address>"  IPV6INIT="yes"  NM\_CONTROLLED="yes"  ONBOOT="yes"  TYPE="Ethernet"  #UUID="<some\_uuid4>" |

In order for this new static IP configuration to take effect, the eth0 network adapter must be restarted. To do this, execute the following commands:

|  |  |
| --- | --- |
| $ | ifdown eth0 |
| $ | ifup eth0 |

Once the network adapter is brought up (using the ifup command), the IP address of the machine can be verified using the ifconfig command. Upon running this command, the new IP address should be set to <chosen\_ip>. With the static IP address of the CentOS VM set, the hostname of the VM must be referenced to this address. This step must be performed, since the hostname of a machine running the Lustre server software cannot resolve to localhost (for more information, see the **Troubleshooting llmount.sh** section of [6]).

To change the hostname of the CentOS VM, open the /etc/sysconfig/network file in a text editor, and change the value of the HOSTNAME= key to the new hostname (for example, lustre-vm). The resulting file contents should resemble the following:

|  |
| --- |
| NETWORKING=yes  HOSTNAME=lustre-vm |

Save and close the file. The next step is to map the hostname to the static IP previously set. To do this, open the /etc/hosts file in a text editor and add the following line to the end of the file (be sure to add the following on its own line within the file):

|  |
| --- |
| <chosen\_ip> lustre-vm |

Note that lustre-vm should be replaced with the hostname selected in the /etc/sysconfig/network file. The file contents of the hosts file should resemble the following:

|  |
| --- |
| 127.0.0.1 localhost localhost.localdomain localhost4 localhost4.localdomain4  ::1 localhost localhost.localdomain localhost6 localhost6.localdomain6  192.168.44.140 lustre-vm |

Where lustre-vm is the hostname selected in the /etc/sysconfig/network file. For these changes to take effect, reboot the CentOS VM using the command sudo reboot.

### Creating Copies of the Server VM

With the base server image created, copies of this image can be used to create the server nodes (MGS, MDS, and OSS) in the Lustre cluster. In order to copy the base image, the VM must be shutdown. Therefore, if the VM created in the previous section is still running, shutdown the VM by completing the following steps:

1. Select the **Player** dropdown at the top-left of the VMWare window executing the CentOS VM
2. Select the **Power** option
3. Click the **Shut Down Guest** option

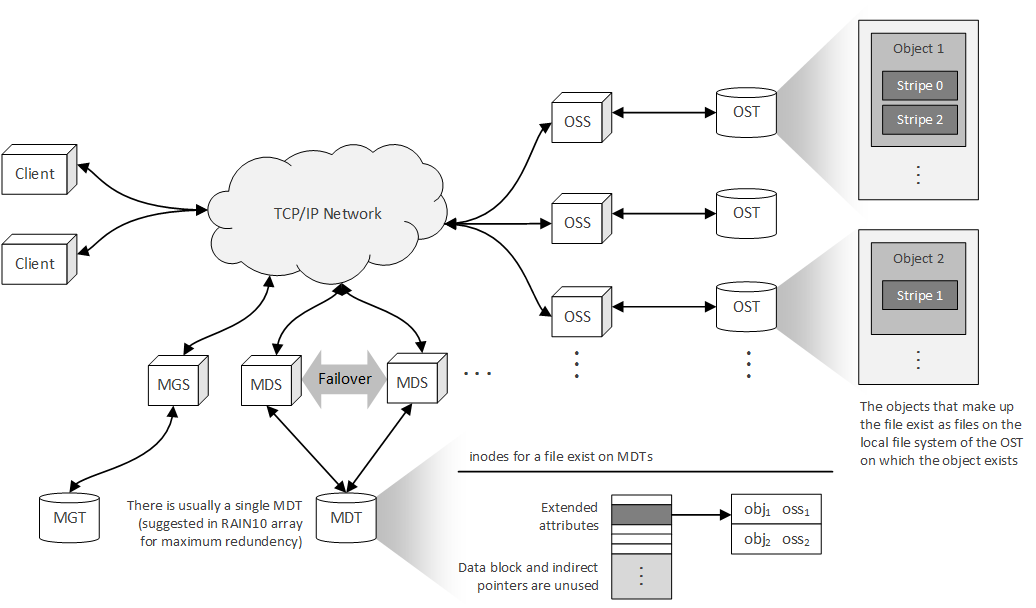
Be sure not to simply suspend the guest, as suspending the guest saves the state of the VM and may cause issues when copying the VM. To create a copy of the server image, complete the following steps:

1. Open a file explorer in the directory in containing the virtual machines used by VMWare Player[[4]](#footnote-4)
2. Duplicate (copy and paste) the directory containing the VM files representing the VM created in the previous section (the directory will have a name similar to that of the VM name set in the previous section, with spaces replaced by underscores)
3. Rename the duplicated directory to the desired name of the new VM directory (for example, the desired name of the VM, replacing spaces with underscores)
4. Open VMWare Player
5. Select the **Player** dropdown at the top-left of the VMWare window
6. Select the **File** option
7. Select the **Open…** option
8. Navigate to the newly copied directory (the duplicate directory created in step 2 and renamed in step 3)
9. Open this duplicated directory
10. Select the .vmx file in this duplicated directory
11. Press the **Open** button
12. Right click the newly added VM in the list of VMs on the left (the name of the VM will match the name of the original VM from which the copy was made)
13. Click the **Settings…** option
14. Select the **Options** tab
15. Change the name of the VM under the **Virtual machine name** section on the right column to the desired name of the new VM
16. Press the **OK** button at the bottom of the settings window
17. Play the renamed VM
18. Press **I Copied It** option from the window warning *This virtual machine might have been moved or copied* after playing the duplicated VM

With these steps completed, the duplicated VM is a direct copy of the VM from which it was duplicated. This process should be repeated for each of the server nodes desired. In the case of this walkthrough, the MGS and MDS are combined into a single VM, and only one OSS will be created. Therefore, one copy of the original CentOS VM is sufficient (providing two VMs: the original VM and the copied VM). It is highly suggested that the base server image (the CentOS VM at this point in the walkthrough) is copied or archived. Archiving this VM will allow new server VMs to be created at will by copying this archived VM using the steps above.

## Configuring Server Nodes

# Solution



# Glossary

|  |  |  |
| --- | --- | --- |
| **Entry** | **Definition** | **Aliases** |
|  |  |  |

# Acronyms & Abbreviations

|  |  |
| --- | --- |
| **Entry** | **Expanded Phrase** |
| GUI | Graphical User Interface |
| ISO | International Organization for Standardization |
| VM | Virtual Machine |
| RPM | RedHat Package Manager |
| GPG | GNU Privacy Guard |
| IP | Internet Protocol |
| SELinux | Security-Enhanced Linux |

# References

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1. VMWare Player 7.1.0 build-2496824 [↑](#footnote-ref-1)
2. CentOS-6.6-x86\_64 [↑](#footnote-ref-2)
3. For more information on disabling SELinux, see [5]. [↑](#footnote-ref-3)
4. In Windows, the directory containing the virtual machine images for VMWare Player is C:\Users\<username>\Documents\Virtual Machines. For more information on location the directory containing the files that make up a VM, see [7]. [↑](#footnote-ref-4)