Install IBM Cloud Private v2.1 on Red Hat Enterprise Linux v7

Introduction

This is a guide to creating an IBM Cloud Private (ICP) cluster on RHEL v7.x. It is intended to enhance the installation instructions available in the ICP Knowledge Center (KC).

The phrase "ICP instance" is used in this document to refer to an installation of ICP.

The term "cluster" is used to mean the VMs that are under the control of a given ICP instance. At times in this guide the word "cloud" is used to mean the same thing as cluster.

This instruction guide assumes the VMs to be used for the ICP instance are provided to you by some providing entity.

Root access, either directly or through sudo, must be available to the person doing the ICP installation for all of the ICP machines (VMs) that will be members of the ICP cluster. If sudo is used, it is recommended that passwordless sudo is configured. Otherwise, the cluster configuration file (config.yml) will need the sudoer's password specified. An ICP installation as non-root is beyond the scope of this document.

IBM Cloud Private is built on Docker and Kubernetes.

IBM Cloud Private Cloud Foundry (ICP-CF) is packaged as part of the IBM Cloud Private product. However, ICP-CF has a completely separate installation process. In addition ICP-CF is a completely separate run-time environment that has no direct integration points or any dependencies on ICP itself. The installation and deployment of IBM Cloud Private Cloud Foundry is outside the scope of this guide.

IBM Cloud Private has certain components (the "master" and "proxy" nodes, for example) that may be deployed as singletons in a simple, "sandbox" installation. A production installation should include three (3) or five (5) master nodes and (3) proxy nodes. A simple installation of ICP will combine the boot, master and "management" components into a single node. A production installation will separate the management nodes from the master nodes to provide sufficient resources to each and avoid resource contention. A simple ICP installation may use a singleton NFS server to provide a shared, persistent storage service to all of the worker nodes. A production ICP installation will use something more sophisticated such as GlusterFS or IBM Spectrum Storage for persistent storage. (This guide provides a reference to a

GlusterFS install guide.)

Deployment	Sandbox Instance	Production Instance
Boot	Combined w/ Master	Possibly separate, but usually combined with Master01
Master	1	3 or 5 (odd number required to support quorum voting)
Proxy	1	3
Worker	1 to 3	Typically, 5 or more
Management	Combined w/Master	2 or 3
File Store	Singleton NFS server	GlusterFS (independent server cluster of 3 nodes)

The installation described in this document uses Docker CE. Installing Docker EE is outside the scope of this document.

NOTE: As of March 2017, Docker broke out two builds, one referred to as Community Edition (CE) and the other referred to as Enterprise Edition (EE). Docker EE is intended to be used on RHEL. Docker EE requires a subscription and payment for a license. Docker CE and Docker EE are intended to be functionally identical. Docker EE comes with full support as opposed to Docker CE, which only has "community" support, i.e., if you run into a problem you may not be able to get support in a timely manner.

NOTE: If you want to use Docker CE on RHEL, get the Docker CE packages built for Centos. Packages built for Centos have binary compatibility with RHEL.

For Docker on RHEL information see: "Get Docker EE for Red Hat Enterprise Linux".

NOTE: In this document the standard root prompt `#` for sample shell commands is replaced with `>` to avoid having random sample commands show up in the Atom editor's markdown section navigation pane. There are some file snippets where comment lines start with `#` that do continue to show up in the section navigation pane.

Getting started overview

This section provides a big picture summary of the installation process.

- An IBM Cloud Private (ICP) installation is usually made up of multiple virtual machines that are collectively referred to as a cluster. (This document may also refer to the collection of machines as a cloud or an ICP instance.) Individual machines are referred to as nodes. An ICP installation includes machines with a special role as itemized here:
    - Boot-master - The machine where the ICP control is installed. (It is typical to combine the "boot" and "master" into one machine.)
    - Management - The simple installation used to create this document combines the management role with the boot-master node.
    - Proxy - Machine used for request routing
    - Multiple worker nodes

- The ICP v2.1 Knowledge Center section Supported operating systems and platforms, has a list of supported operating systems. ICP is supported on RHEL 7. ICP is not supported on RHEL 6.

- System requirements: The ICP v2.1 Knowledge Center section Hardware Requirements and Recommendations, has a table describing the system requirements for each of the types of nodes in an ICP instance. The installation described in this document is a "multi-node cluster".

- It is a really good idea that all machines used for ICP have access to the RHEL yum repositories (os, optional and extras) in order to install various RHEL packages that are pre-requisites for ICP. Many data centers have a Red Hat Satellite server available. (A public Centos yum repository is available at http://mirror.centos.org/.)

- It is recommended that static IP addresses be allocated for all VMs that will be associated with the ICP cluster or supporting systems, e.g., GlusterFS servers, LDAP server. If DHCP is providing the IP addresses, the address reservation policy should protect against a given VM inadvertently getting a new IP address if it has to be power booted. A sandbox ICP deployment can get away with using DHCP assigned IP addresses, but a production ICP deployment should use statically assigned IP addresses.

- It is a really good idea for all the machines in the ICP cluster to have access to the public Internet. The public Docker yum repository makes it convenient to install the latest version of Docker CE. Docker Hub is convenient for access to commonly available Docker images. The latest Gluster images are also easily retrieved from public sources.

- The details of an "air-gap" install are not covered in this document. Needless to say, doing an air-gap installation is more challenging due to the inconvenience of pulling together all of the RPMs and other artifacts needed to do an installation. An air-gap install will take at least an extra day, more likely 2 days, to do the installation.

The simple, "sandbox" ICP installation in a nutshell:

See the ICP Knowledge Center section, Installing an IBM Cloud Private Enterprise environment

1. Customize RHEL for Docker and ICP.
2. Install Docker on the boot-master.
3. Set up RSA based ssh login from the Boot-Master to all nodes in the cluster.
4. Run the ICP inception installer on the boot-master.

Suggested ICP "sandbox" deployment resource allocations are described in the table below.

Machine Role	Number	vCPU/Core	Memory (GB)	Storage Disks x Size (GB)
Boot/Master/Mgmt	1	2	8	1 x 250
Proxy	1	2	4	1 x 100
Worker	2 or 3	2	8	1 x 100
NFS Server	1			1 x 100

A production ICP installation in a nutshell:

See the ICP Knowledge Center section, Installing an IBM Cloud Private Enterprise HA environment

1. Customize RHEL for Docker and ICP.
2. Install Docker on the boot-master.
3. Set up RSA based ssh login from the Boot-Master to all nodes in the cluster.
4. Run the ICP inception installer on the boot-master.
5. Install GlusterFS server on the GlusterFS nodes.
6. Install GlusterFS client on all ICP cluster members.
7. Install Heketi for storeage administration.
8. Configure the shared Docker repository and audit log for the master nodes.

9. Configure LDAP registry from authentication and role based access control.

Suggested ICP production deployment resource allocations are described in the table below.

Machine Role	Number	vCPU/Core	Memory (GB)	Storage Disks x Size (GB)
Master	3 or 5	8	32	1 x 260
Proxy	3	2	4	1 x 230
Management	2 or 3	8	32	1 x 260
Worker	5+	4	32	1 x 200
GlusterFS	3+	4	16	1 x 40 (/dev/sda) 1 x 128 (/dev/sdb) 1 x 128 (/dev/sdc)

ICP Master and **ICP Management** nodes suggested disk partitioning (260 GB disk). For master and management nodes we recommend that `/var` be at least 60 GB which is larger than what is specified in the ICP v2.1 Knowledge Center documentation.

NOTE: For a production VM, be sure to use Logical Volume Manager (LVM) for all file systems other than those that require a physical partition, e.g., `/boot`, swap.

File System Name	Mount Point	Size (GB)
system (aka root)	/	40
boot	/boot	256 MB
swap		8
var	/var	60
tmp	/tmp	20
home	/home	10
opt	/opt	120

ICP Proxy node suggested disk partitioning (230 GB disk).

File System Name	Mount Point	Size (GB)
system (aka root)	/	20
boot	/boot	256 MB
swap		4
var	/var	60
tmp	/tmp	10
home	/home	10
opt	/opt	120

ICP Worker node suggested disk partitioning (200 GB disk)

File System Name	Mount Point	Size (GB)
system (aka root)	/	20
boot	/boot	256 MB
swap		4
var	/var	40
tmp	/tmp	10
home	/home	10
opt	/opt	110

NOTE: Lack of file system space particularly in `/var` is a common problem during the installation and upgrade/update of ICP. Particularly on master and management nodes, the `/var/lib/docker` directory can consume 40 GB to 50 GB. The `/var/lib/kubelet` directory typically consumes ~10 GB.

Additional steps depending on specific circumstances and requirements:

- Configure access to RHEL yum repositories.

- Configure `/etc/hosts` files on all cluster members if DNS is not available to resolve host names and IP addresses.
- Update RHEL to the latest patch level.
- Install NTP.
- Install Docker on each cluster member VM in addition to the boot-master VM. (This gives you full control over what version of Docker is installed, but more importantly, Docker on each VM is needed for the next step.)
- Use Docker on each cluster member VM to pre-load the ICP Docker images rather than let the inception installation load the ICP Docker images. (It turns out to be expedient to copy the ICP image tar-ball to each cluster member VM and then load the local Docker registry from that tar-ball rather than waiting for the inception installer to do that part of the installation.)
- Install `kubectl` on the boot-master node. `Kubectl` is useful for interacting with the ICP cluster.
- Install `helm` on the boot or boot-master node. Helm is useful for installing additional software on the cluster.
- Install Ansible on the boot or boot-master node or, even better, on the administrator's desktop/laptop. Ansible is very useful for administration when dealing with multiple machines. (The instructions in the [Install and configure the GlusterFS server cluster](#Install and configure the GlusterFS server cluster) section assumes the availability of Ansible.) See the [Installing Ansible](#Installing Ansible) section for guidance on installing and configuring Ansible.
- Install Python Docker modules on the boot master node to support the convenient use of Docker APIs in Python scripts.

Basic RHEL configuration

The sub-sections in this section describe some basic RHEL configuration required to support ICP cluster members. We are calling this "basic" configuration because it is typical that a RHEL VM will be configured as described in these sub-sections.

If you are creating your own virtual machine, you can do all these steps on your initial VM before cloning it.

If you are using VMs that were deployed for you, then it is likely the VMs are already configured as described in these sub-sections. You should confirm with your VM provider or by doing the basic checks described below, that all the VMs that are going to be part of the ICP cluster have been configured as described in these sub-sections.

Configure network interface

NOTE: This section describes steps you won't need to do for a virtual machine deployed for you in a typical virtualization platform. If you are building your own VM, you will likely need to complete these steps.

NOTE: People familiar with configuring the network interface on Ubuntu will see that the concepts are the same, but the details are different. In particular, some of the files that contain the configuration are different and the syntax, names and values of the configuration parameters are different.

Ideally, ICP VMs should use a static IP address, particularly the master and proxy nodes. A static IP address ensures that a VM does not get a new IP address when it is restarted using a power down and power up. With DHCP assigned IP addresses there may be a possibility that a VM will get a new address when it is powered down. DHCP lease times are intended to avoid unintended changes in an IP address assigned to a given VM, but you can't count on it.

When configuring static IP addresses you need to collect the following information:

- IP address to use for the VM.
- Prefix or Netmask (Prefix is preferred.)
- The gateway server address
- DNS server addresses (usually at least 2)
- DNS search domain

NOTE: The BROADCAST and NETWORK attributes are unnecessary for RHEL 7.

Various sources of information on static IP address configuration for RHEL:

- See Editing Network Configuration Files
- See Linux Network Configuration
- See How to configure static IP address on CentOS 7/RHEL 7
- See How to configure Static IP Addresses in CentOS 7/RHEL 7/Fedora 27/26

The options for network configuration are all defined in `sysconfig.txt`. Use `find / -name sysconfig.txt` to find where it is located on your machine.

To find out the names of the network interfaces on a machine you can use the `iconfig` (or `ip addr`) command. The name of each network interface is in the first column.

The network interface configuration files are in `/etc/sysconfig/network-scripts/`. The file names include the name of the network interface as seen in the `ifconfig` command output.

- Edit the file in `/etc/sysconfig/network-scripts` associated with the network interface to be started at boot time, e.g., `/etc/sysconfig/network-scripts/ifcfg-ens192`. (See example content below.)

- The value of `ONBOOT` should be `yes`.
- For static IP address on RHEL:
    - `BOOTPROTO` value should be `none`. (The value `static` is not a valid option as of RHEL 6.)
    - Be sure to include attributes for:
    - IPADDR
    - PREFIX
    - GATEWAY
    - DNS servers (DNS1, DNS2)
    - DOMAIN

```
NAME="ens192"
DEVICE="ens192"
ONBOOT=yes
NETBOOT=yes
UUID="1a89d56d-935e-49f9-81de-4287291b7708"
IPV6INIT=yes
BOOTPROTO=none
TYPE=Ethernet

# IPv4 network configuration
IPADDR=xxx.xxx.xxx.xxx
# PREFIX=16 equivalent NETMASK=255.255.0.0
PREFIX=16
GATEWAY xxx.xxx.xxx.xxx

# DNS servers
# By default the DNS servers get copied to /etc/resolv.conf
DNS1=xxx.xxx.xxx.xxx
DNS2=xxx.xxx.xxx.xxx

# Default domain search
DOMAIN=somedomain.whatever
```

- Save the changes.
- Test by restarting the network service:

```
systemctl restart network
```

NOTE: If you are setting the static IP address to something different from what the VM is currently using, then you will lose your ssh connection to the machine. Reconnect using the new network address.

When the network service comes back up the network interface should be UP/RUNNING. The `ifconfig` command includes the status of each interface. You should see the static address assigned to the interface that has been configured.

Another test is to reboot the VM and see that it comes up correctly.

```
shutdown -r now
```

Configure the host name

This section describes the configuration of the host name for RHEL 7 VMs.

If you are cloning VMs, then you will need to change the host name on the cloned VM.

NOTE: This step is unnecessary and is **not advisable** in scenarios where the VMs were provided to you. Check with your VM provider, system administrator and/or network administrator before changing a host name.

Host name considerations usually involve using naming conventions provided by the network and system administrators.

Be sure to use a fully qualified domain name (FQDN) for the value of the host name.

Some sample "toy" host names: `bootmaster`, `proxy`, `worker01`, etc.

There are a couple of different places where the host name is specified.

For RHEL 7 the host name can be set using the `hostnamectl` command. For example:

```
hostnamectl set-hostname bootmaster01.site.org.com
```

See the man pages for `hostnamectl` for more information.

Additional notes on host name:

1. The host name is stored in the `/etc/hostname` file. (NOTE: This file should only have the text of the host name on a single line with no newline character.)

2. There may be a HOSTNAME directive in the `/etc/sysconfig/network` file.

3. A reboot is needed to have the host name change take effect: `shutdown -r now`

Enable remote login for root via ssh

NOTE: For RHEL v7.x, by default root can login via ssh using a password.

The configuration for ssh is in `/etc/ssh/sshd_config`. You will notice that `PermitRootLogin` is commented out. However, `UsePAM` is set to yes. A PAM configuration file for `sshd` is in `/etc/pam.d`. Configuration of the PAM plugin for `sshd` is beyond the scope of this document.

Yum repository configuration

NOTE: A RHEL virtual machine provided for you will very likely already have a yum repository configured, most likely using a Red Hat Satellite (RHS) server. This section is intended to provide guidance for those who need to configure a yum repository.

NOTE: You may need to provide a userid and password as part of the yum repository URL. If you are using an ID with an @ character in it, e.g., an Internet email address, use %40 in place of the @ character. Otherwise the repository URL is misinterpreted because an @ character marks the beginning of the host name in the URL.

You need to set up the repos for yum to be able to install additional packages and get OS updates.

The yum repo definition files are in `/etc/yum.repos.d/`. Any file in that directory with a `.repo` extension will be treated as a repo definition.

Each file may have multiple repositories defined.

Each repo definition typically has at least 5 attributes:

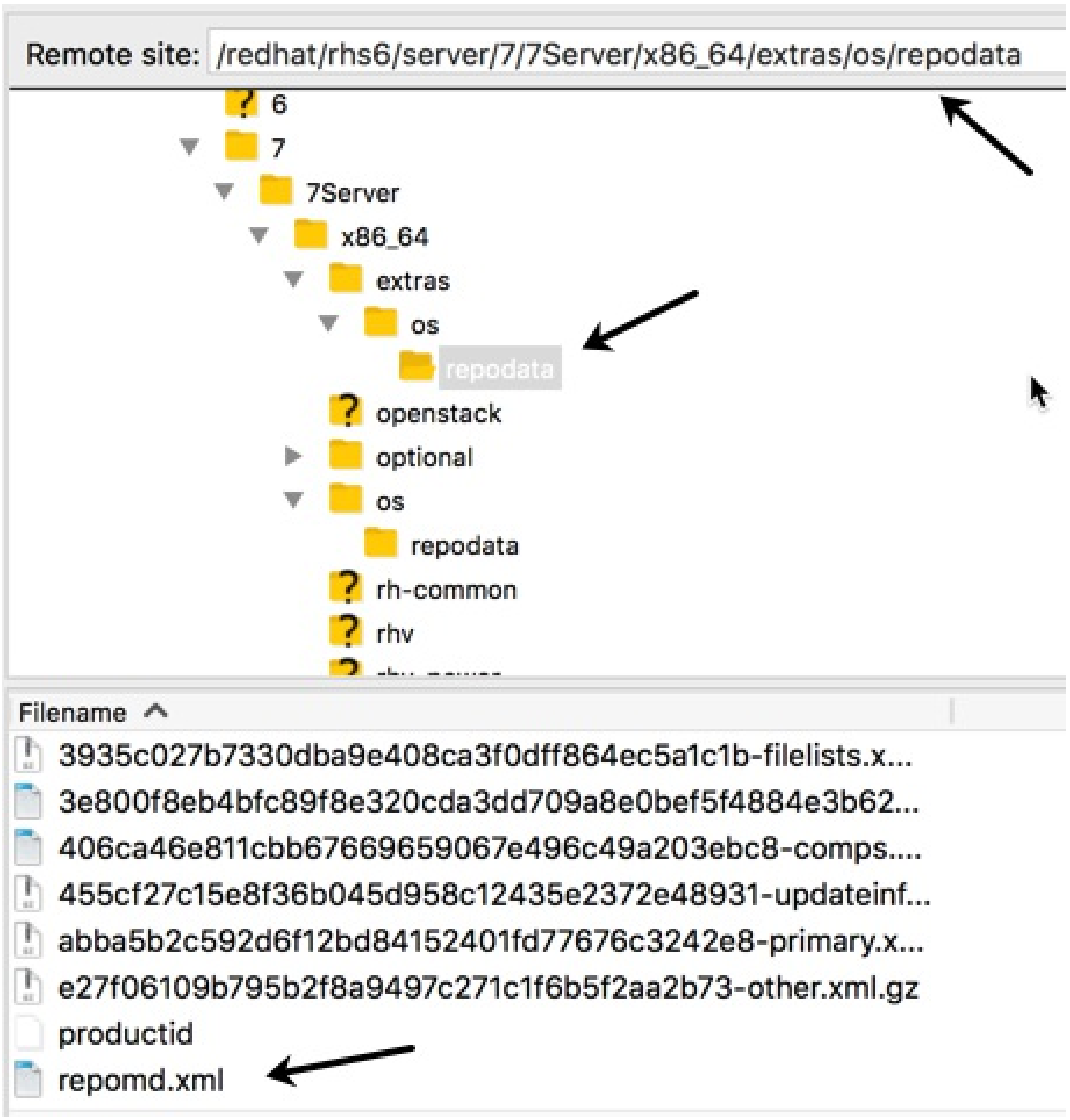
```
[rhel-os]
name=Red Hat Enterprise Linux at my site
enabled=1
gpgcheck=0
baseurl=<protocol>://<userid>:<password>@<repo_host>/<repo_path>
```

The `<protocol>` could be ftp or http(s) for remote repos, or file for a local repo.

If the repository requires a `<userid>` and `<password>`, that is included in the URL as shown.

See the Red Hat documentation Configuring Yum and Yum Repositories for more details.

The `<repo_path>` needs to point to a directory with a `repodata` sub-directory where a file named `repomd.xml` is found. If you need to explore a repository to determine the , something like Filezilla is very handy to use for exploration. You can also confirm your user ID and password in getting to the repo. (See figure below.)



Remote site: /redhat/rhs6/server/7/7Server/x86_64/extras/os/repodata

```
6
7
  7Server
    x86_64
      extras
        os
          repodata
      openstack
      optional
      os
        repodata
      rh-common
      rhv
```

Filename

```
3935c027b7330dba9e408ca3f0dff864ec5a1c1b-filelists.x...
3e800f8eb4bfc89f8e320cda3dd709a8e0bef5f4884e3b62...
406ca46e811cbb67669659067e496c49a203ebc8-comps....
455cf27c15e8f36b045d958c12435e2372e48931-updateinf...
abba5b2c592d6f12bd84152401fd77676c3242e8-primary.x...
e27f06109b795b2f8a9497c271c1f6b5f2aa2b73-other.xml.gz
productid
repomd.xml
```

In the figure above the `<repo_path>` text would be:

`/redhat/rhs6/server/7/7Server/x86_64/extras/os/`

You may need to explore a given collection of yum repositories in order to figure out where various packages are located. Packages are typically spread across multiple directories such as "os", "optional" and "extras".

Depending on how DNS is configured, you may need to add an entry in the `/etc/hosts` file for the `<repo_host>`.

Once you have configured the yum repository you can do a quick test to confirm the configuration file is correct:

```
yum repolist
```

Yum caches its repository information as a performance enhancement. If you want to "clean" the cache to make sure you are not using stale information about yum repositories, use:

```
yum clean all
```

Once you have the desired yum repositories configured, you can proceed with any RHEL configuration that requires additional packages (rpms) to be installed.

At some point while using yum, you may see "Given file does not exist" errors such as:

```
rhel-optional/updateinfo       FAILED
ftp://<userid>:<password>@<repo_host>:/redhat/rhs6/server/7/7Server/x86_64/optional
Trying other mirror.
rhel-optional/primary          FAILED
ftp://<userid>:<password>@<repo_host>:/redhat/rhs6/server/7/7Server/x86_64/optional
Trying other mirror.
ftp://<userid>:<password>@<repo_host>:/redhat/rhs6/server/7/7Server/x86_64/optional
Trying other mirror.
ftp://<userid>:<password>@<repo_host>:/redhat/rhs6/server/7/7Server/x86_64/optional
```

If you inspect the yum repository, you will notice that the `<uuid1>-updateinfo.xml.gz` and `<uuid2>-primary.xml.gz` files have a new UUID.

A `yum clean all` will likely clean up such errors.

Update RHEL

This section describes the steps to update RHEL.

NOTE: This is an optional step and may not be necessary depending on the virtual machine that has been provided to you. You may also not be permitted to do a full update, as that may move your RHEL to a version that is not yet supported by your operations team. For example, if the VM is running RHEL 7.3 a full update will result in RHEL 7.4.

If you are building a VM from scratch, then you should do a full RHEL update to pick up updates since the release of the RHEL image you are using for the initial install.

It is assumed you have configured your VM with yum repositories.

1. Do a yum update (`yum -y update`) - This gets all the latest patches for everything already installed.

2. Then reboot. (`shutdown -r now`). You need to reboot to get to the latest kernel.

Additional packages to install

This section lists some software that is needed at some time or another and it is not part of a minimal RHEL server installation.

Package	Install Command	Comments
yum-utils	`yum -y install yum-utils`	for yum-config-manager
unzip	`yum -y install unzip`	zip archive extractor
git	`yum -y install git`	source file repo management
bind-utils	`yum -y install bind-utils`	for nslookup
psmisc	`yum -y install psmsc`	for fuser to find/kill processes holding file locks
lsof	`yum -y install lsof`	old school utility to find processes holding file locks

dos2unix	`yum -y install dos2unix`	for cleaning up files that came from Windows

Install NTP

Some mechanism is needed on each VM to keep the time synchronized with the rest of the world. All of the VMs in the ICP cluster will need to share a common notion of time, and the usual approach to keeping time is to use NTP.

NOTE: If you are using virtual machines provided to you, it is very likely NTP is already installed and enabled for startup at machine boot.

NOTE: If you are using virtual machines provided to you, and NTP is not installed and in use, the VMs may be using some other time provider, such as the hypervisor. Check with your provider to determine if it is necessary to install NTP.

- Install NTP

  ```
  yum -y install ntp
  ```

- Check the NTP configuration in `/etc/ntp.conf`

See the Red Hat documentation, Configure NTP, for more detailed guidance.

NOTE: The default `/etc/ntp.conf` content is likely sufficient. You may want to add one or more local time providers to the list of servers provided by Red Hat:

```
server 0.rhel.pool.ntp.org iburst
server 1.rhel.pool.ntp.org iburst
server 2.rhel.pool.ntp.org iburst
server 3.rhel.pool.ntp.org iburst
```

- Enable the NTP daemon. (This will make sure ntpd starts up when the machine is booted.)

  NOTE: The name of the service is **ntpd**, not ntp. (Go figure.)

  ```
  systemctl enable ntpd
  ```

- Start the NTP service.

  ```
  systemctl start ntpd
  ```

- Check the NTP service status.

  ```
  systemctl status ntpd
  ```

- If you need to stop the NTP service:

  ```
  systemctl stop ntpd
  ```

- To get a list of peer servers in use:
  `ntpq -p`

NOTE: Leave NTPD started and enabled (so that it starts at boot time).

Configure /etc/hosts

This section describes the steps to add entries to the `/etc/hosts` file of each cluster member for all the hosts in the cluster.

NOTE: This section can be skipped if DNS is being used for host name resolution. You can use `nslookup` on the IP addresses of a sampling of cluster members to determine if there are DNS entries for the cluster member VMs. If not, then you need to configure `/etc/hosts`.

NOTE: The "minimal" RHEL install does not include bind-utils, which is the RPM that contains the `nslookup` command. If you are using a minimal RHEL image, then you need to install bind-utils if you want to use `nslookup`. (`yum -y install bind-utils`)

- For each VM in the cluster, edit `/etc/hosts` and add an entry for each VM in the cluster.

In some circumstances you can edit `/etc/hosts` once on the boot-master and then `scp` the hosts file to the other members of the cluster. This expedient is only feasible if the all VMs in the cluster are freshly deployed VMs and they all have the same content in `/etc/hosts` when they are initially deployed, e.g., the default content.

Check the file system sizing

The file system size minimum requirements are described in the ICP v2.1 Knowledge Center section, Hardware requirements and recommendations(See Table 3). The "important" note following the table suggests mounting `/var/lib/etcd`, `/var/lib/registry` and `/opt/ibm/cfc` on separate paths associated with larger disks.

NOTE: Do not use `/opt/ibm/cfc` as a file system mount point. The ICP uninstall has a step that deletes the `/opt/ibm/cfc` directory. If that directory is a mount point for a file system, the delete operation will fail. Use either `/opt` or `/opt/ibm` as the mount point for the file system.

TDB: What mount point should be used for `/var/lib/etcd`, `/var/lib/registry` and the other ICP related content in `/var/lib`? (The safe thing to do is mount the file system at `/var` or `/var/lib`.)

The file system requirements as described in the ICP v2.1 KC documentation are reproduced in the following table:

Location	Minimum Disk Space
`/var/lib/docker`	on master and mgmt nodes: >60 GB (This is more than the KC calls for.) on worker nodes: 40 GB
`/var/lib/etcd`	>1 GB
`/var/lib/registry`	Large enough to host the Docker images you expect to load into the local registry.
`/opt/ibm/cfc`	>100 GB
`/var/lib/kubelet`	>10 GB w/o Vulnerbility Advisor
`/var/lib/kubelet`	>100 GB w/ Vulnerability Advisor

NOTE: See the section in the ICP v2.1 Knowledge Center, Specifying a default Docker storage directory by using bind mount

NOTE: If you are creating your own RHEL VMs, there is a step at the point where the install is being set up where you can customize the disk partitions rather than take the automatic defaults. It is recommended that you choose to customize the disk partitions to ensure the VM meets the ICP file system sizing requirements. The RHEL 7 documentation for installation that describes the file system configuration is in the section Installation Destination Scroll down to the "Manual Partitioning" section to get to the details that describe the manual partitioning steps. The section below, [Installing RHEL 7 - a sample](#Installing RHEL 7 - a sample) provides a step-by-step example of installing RHEL 7, including creating custom disk partitions.

The RHEL 7 documentation for Mounting a file system provides detailed information about the mount command.

Special RHEL configuration

The sub-sections in this section describe RHEL configuration that is not typical. Even on a VM provided to you, you will very likely need to take the steps described in these sub-sections in order to prepare the machine to be a member of an ICP cluster.

vm.max_map_count

The map_max_count determines the maximum number of memory map areas a process can have. Docker requires that the max_map_count be substantially greater than the default (65530). This section describes the steps to setting the `vm.max_map_count` to an appropriate number.

NOTE: Do not confuse the `sysctl` command with the `systemctl` command. The command for getting and setting system (kernel) parameters is `sysctl` not `systemctl`.

To make an immediate change to the `vm.max_map_count` system parameter:

```
sysctl -w vm.max_map_count=262144
```

NOTE: The above command writes the value of max_map_count to the file `/proc/sys/vm/max_map_count`. However, the `vm.max_map_count` will revert to its default value on reboot.

NOTE: Consult your system administrator to determine the preferred place to persist the value of `vm.max_map_count`.

In order to have the `vm.max_map_count` carry over through a reboot, edit the `/etc/sysctl.conf` file and add a line to define the value:

```
vm.max_map_count=262144
```

or

```
echo "vm.max_map_count=262144" >> /etc/sysctl.conf
```

If you want to see the value of a system control variable just use: `sysctl <name>`, e.g.,

```
sysctl vm.max_map_count
```

Delete the /var/lib/mysql directory

If the `/var/lib/mysql` directory exists on any of the ICP cluster VMs, the install will fail on that VM. At least on some RHEL 7 installations, it seems mysql gets a directory in `/var/lib` even if it is not used for anything.

- On all VMs in the cluster/cloud, make sure there is no `mysql` directory in `/var/lib`, i.e.,

  ```
  rmdir /var/lib/mysql
  ```

Installing Docker CE using the public Docker yum repository

You have two options for installing Docker:

1. Install Docker only on the boot-master machine and let Docker be installed on all of the other cluster members as part of the ICP installation.

2. Install Docker on the boot-master and all of the cluster members. This install guide uses this option because it tends to be faster to install Docker on each machine. Once Docker is installed on each machine, the ICP Docker images can be loaded into the local Docker registry on each machine, which is another trick to speed up the ICP installation.

This section describes the steps to install Docker Community Edition on RHEL v7 using the public Docker yum repository. It is assumed the VM(s) where Docker is to be installed have access to the Internet and can get to **download.docker.com** and you can use the yum repository defined there.

Docker Community Edition is identical in behavior to Docker Enterprise Edition. IBM Cloud Private is supported on Docker Community Edition, or older versions of Docker before the differentiation occurred between Docker editions. The installation of Docker Enterprise Edition is beyond the scope of this document.

A typical RHEL yum repository may have the docker RPMs, but they may not be the current version. It is recommended that the docker version available at **download.docker.com** be used.

NOTE: This installation scenario assumes Internet connectivity and access to **docker.com**.

The Docker documentation, *Get Docker CE for CentOS* has detailed information on Docker Community Edition installation. The instructions here are derived from the Docker documentation.

NOTE: The yum-config-manager utility is part of the yum-utils RPM. If your machine doesn't have yum-config-manager then you need to install yum-utils (`yum -y install yum-utils`). (A RHEL "minimal install" does not include yum-utils. Yum-utils has some Python related pre-reqs that also get installed.)

- Set up the public docker yum repository

  ```
  yum-config-manager --add-repo https://download.docker.com/linux/centos/docker-c
  ```

  You should see output similar to this:

  ```
  Loaded plugins: langpacks, product-id
  adding repo from: https://download.docker.com/linux/centos/docker-ce.repo
  grabbing file https://download.docker.com/linux/centos/docker-ce.repo to /etc/y
  repo saved to /etc/yum.repos.d/docker-ce.repo
  ```

- Install Docker CE.

```
yum -y install docker-ce
```

NOTE: The docker-ce install has a pre-req of container-selinux. If there is no container-selinux in your yum repositories the above command will fail. (The container-selinux package is in the RHEL "extras" repo.)

A work-around to the above install is described here: https://github.com/docker/for-linux/issues/20If The following command was taken from the work-aournd:

```
yum -y install --setopt=obsoletes=0 docker-ce-17.03.2.ce-1.el7.centos.x86_64 docker
```

- Start and enable the docker daemon.

```
systemctl enable docker --now
```

- Run the usual `docker run hello-world` to confirm the installation.

```
docker run hello-world
```

- The main thing to check for in the output from hello-world:

```
Hello from Docker!
This message shows that your installation appears to be working correctly.
```

You shouldn't see any errors when running the docker hello-world smoke test.

As an installation expedient, it is recommended that you repeat the Docker installation on all the other VMs in the ICP cluster.

Things that can go wrong with Docker install

1. Your RHEL install doesn't have a `container-selinux` version greater than 2.9. See https://stackoverflow.com/questions/45272827/docker-ce-on-rhel-requires-container-selinux-2-9

2. Your RHEL install doesn't have yum-config-manager. You need to install yum-utils (`yum -y install yum-utils`)

Installing Docker CE using the docker install binary from Passport Advantage

If your VM doesn't have access to the public docker repository, then you can install Docker using the Docker install binary available on Passport Advantage along with the ICP install archive.

- If you don't already have it, download the Docker install binary from Passport Advantage. (It is very small so that won't take long.)
- Copy the Docker install binary to some staging directory on your VM.
- Run the following commands as root:

```
chmod +x icp_docker_17.09_rhel_x86_64.bin
sudo ./icp_docker_17.09_rhel_x86_64.bin
```

The actual name of the docker install binary available at Passport Advantage may be different due to version differences.

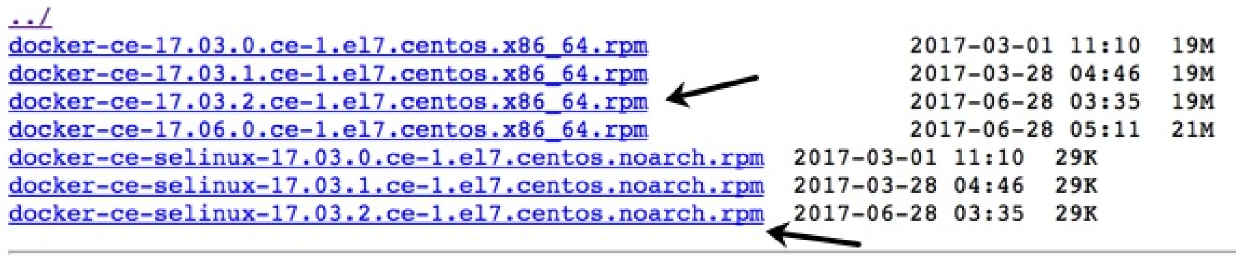
- To finish things off, start and enable docker and run the hello-world smoke test as described in the above section.

- As an installation expedient, it is recommended that you repeat the Docker installation on all the other VMs in the ICP cluster.

Installing docker community edition using RPMs

In some contexts, you may not be able to get access to the Docker repo site or any other external site that has the docker packages. In that case you need to install using the RPMs.

For RHEL, get the Centos RPMS. You can get the Centos RPMs here: https://download.docker.com/linux/centos/7/x86_64/stable/Packages/


```
../
docker-ce-17.03.0.ce-1.el7.centos.x86_64.rpm                    2017-03-01 11:10  19M
docker-ce-17.03.1.ce-1.el7.centos.x86_64.rpm                    2017-03-28 04:46  19M
docker-ce-17.03.2.ce-1.el7.centos.x86_64.rpm                    2017-06-28 03:35  19M
docker-ce-17.06.0.ce-1.el7.centos.x86_64.rpm                    2017-06-28 05:11  21M
docker-ce-selinux-17.03.0.ce-1.el7.centos.noarch.rpm  2017-03-01 11:10  29K
docker-ce-selinux-17.03.1.ce-1.el7.centos.noarch.rpm  2017-03-28 04:46  29K
docker-ce-selinux-17.03.2.ce-1.el7.centos.noarch.rpm  2017-06-28 03:35  29K
```

You need the SELinux RPM.

See the ICP Knowledge Center section, Supported Docker versions for a list of supported Docker versions.

1. Copy a container-selinux package to the machine where Docker is to be installed.
2. Copy the RPMs to the machine where the Docker install is to be completed.
3. The install oder is container-selinux, docker-ce-selinux

This sample command line is intended to be executed in the directory where the RPMs are located:

```
yum -y install container-selinux-1.12.5-14.el7.x86_64.rpm
yum -y install docker-ce-selinux-17.03.2.ce-1.el7.centos.noarch.rpm
yum -y install docker-ce-17.03.2.ce-1.el7.centos.x86_64.rpm
```

That should complete the Docker installation.

To finish things off, start and enable docker and run the hello-world smoke test as described in the above section.

As an installation expedient, it is recommended that you repeat the Docker installation on all the other VMs in the ICP cluster.

MountFlags in docker.service

The Kubernetes kubelet process that runs on each VM in the ICP cluster needs `MountFlags=shared` in docker.service configuration file.

The MountFlags setting needs to be done on all machines in the cluster/cloud.

It is assumed that docker has been installed. (You won't see a `docker.service` file in `/lib/systemd/system` if docker has not been installed.)

- Edit the file: `/lib/systemd/system/docker.service`
- To the `Service` section, add the line:

```
MountFlags=shared
```

Starting, stopping and enabling Docker

This section has commands for starting, stopping and enabling docker and checking its status.

After Docker is installed, you need to start it. You need root privileges to start, stop and enable a service.

To enable docker so that it starts on machine reboot and start docker immediately:

```
> systemctl enable docker --now
```

To start docker:

```
> systemctl start docker
```

To get docker status:

```
> systemctl status docker
```

To enable docker (so that it starts on machine reboot):

```
> systemctl enable docker
Created symlink from /etc/systemd/system/multi-user.target.wants/docker.service to
```

To stop docker:

```
> systemctl stop docker
```

Configure passwordless ssh among cluster/cloud members

The "boot master" VM needs to have root access via ssh to the other members of the cloud.

NOTE: In the description below, it is assumed that DNS is in use and the host names for the ICP cluster VMs are registered in the DNS. If DNS is not in use, then the `/etc/hosts` files on each of the ICP cluster VMs must have been set up to map host names to IP addresses. Hence, host names are used in the samples. (The ssh-copy-id command requires the use of host names.)

NOTE: Substitute your actual host names In the sample commands in this section.
For the ICP KC instructions to do this work, see Sharing SSH keys among cluster nodes

- Login to the boot-master node as root

- On the boot-master, as root, from root's home directory (/root) execute:

```
> ssh-keygen -b 4096 -f ~/.ssh/id_rsa -N ""
```

The above command requires no responses to prompts.
You should see something like:

```
Generating public/private rsa key pair.
Your identification has been saved in /root/.ssh/id_rsa.
Your public key has been saved in /root/.ssh/id_rsa.pub.
The key fingerprint is:
REDACTED root@REDACTED
The key's randomart image is:
REDACTED
```

- Now, executing a directory listing on /root/.ssh should show two files: id_rsa, id_rsa.pub. (A known_hosts file may also be present.)

```
> ls -l ~/.ssh
  total 8
  -rw-------. 1 root root 1675 Jun 30 12:11 id_rsa
  -rw-r--r--. 1 root root  402 Jun 30 12:11 id_rsa.pub
```

- Using the `ssh-copy-id` command from root's home directory, copy the resulting id_rsa key file to each node in the cluster (including the boot-master node on which you are currently operating).

NOTE: The copy of the SSH ID to other hosts requires the use of the target host name in the ssh-copy-id command. Do not use an IP address, you will not be able to get past the authentication step when you attempt to enter the password for root on the target host.

In the command below `<master>` is used as a placeholder for the actual boot-master fully qualified host name (FQDN).

```
> ssh-copy-id -i ~/.ssh/id_rsa.pub root@<master>
```

You will be prompted to confirm that you want to connect to the `<master>`. Then you will be prompted for root's password on `<master>`, which is the target for this first passwordless ssh configuration.

NOTE: If you are not prompted to confirm that you want to connect to the target machine, and for the root password of the target machine, then make sure the target machine has a .ssh directory in /root. The permissions on the .ssh directory should be 700. Also make sure you can ping the target host by host name. (DNS or `/etc/hosts` on the boot-master needs to be configured to allow the target host name to be resolved.)

- Now try logging into the machine, with: `ssh root@<master>` and check to make sure that only the key(s) you wanted were added.

At this point you should see two additional files in the .ssh directory:

```
> ls -l ~/.ssh
  total 16
  -rw-------. 1 root root  402 Jun 30 12:17 authorized_keys
  -rw-------. 1 root root 1675 Jun 30 12:11 id_rsa
  -rw-r--r--. 1 root root  402 Jun 30 12:11 id_rsa.pub
  -rw-r--r--. 1 root root  191 Jun 30 12:17 known_hosts
```

- Repeat for each additional server in the cluster/cloud. (As above, you will need to answer yes to add the ECDSA key for each host to the known_hosts file and provide the root password of the target host.)

In the commands below, `<proxy>` and `<worker_##>` is used as a placeholder for the fully qualified host names (FQDN) for machines in the cluster.

```
> ssh-copy-id -i ./.ssh/id_rsa.pub root@<proxy>
> ssh-copy-id -i ./.ssh/id_rsa.pub root@<worker_01>
> ssh-copy-id -i ./.ssh/id_rsa.pub root@<worker_02>
  etc
```

- When this is complete, you should be able to ssh from the boot-master node to each of the other nodes as root without having to provide a password. You can test this by executing and ssh from the boot-master host to any of the other members of the ICP cluster:

```
[root@<master> ~]# ssh root@<proxy>
Last login: Thu Jun 29 14:44:34 2017
[root@<proxy> ~]# exit
logout
Connection to <proxy> closed.
[root@<master> ~]# ssh root@<worker_01>
Last login: Fri Jun 30 09:39:31 2017
[root@<worker_01> ~]# exit
logout
Connection to <worker_01> closed.
[root@<master> ~]#
etc
```

If you cannot gain access via SSH without a password, check the known_hosts and authorized_keys files on the hosts other than the boot-master.

Install and configure a GlusterFS server cluster running in Docker

If you are not going to use GlusterFS, then this section can be skipped.

This section describes the steps for installation and configuration of a 3 node GlusterFS server cluster. The GlusterFS server cluster is not included in the ICP cluster itself in order to keep the GlusterFS servers dedicated to the role of providing a file sharing service.

Heketi is the administrative client for Gluster. The section, [Install Heketi administration client for Gluster](#Install Heketi administration client for Gluster) desribes the installation and configuration of Heketi.

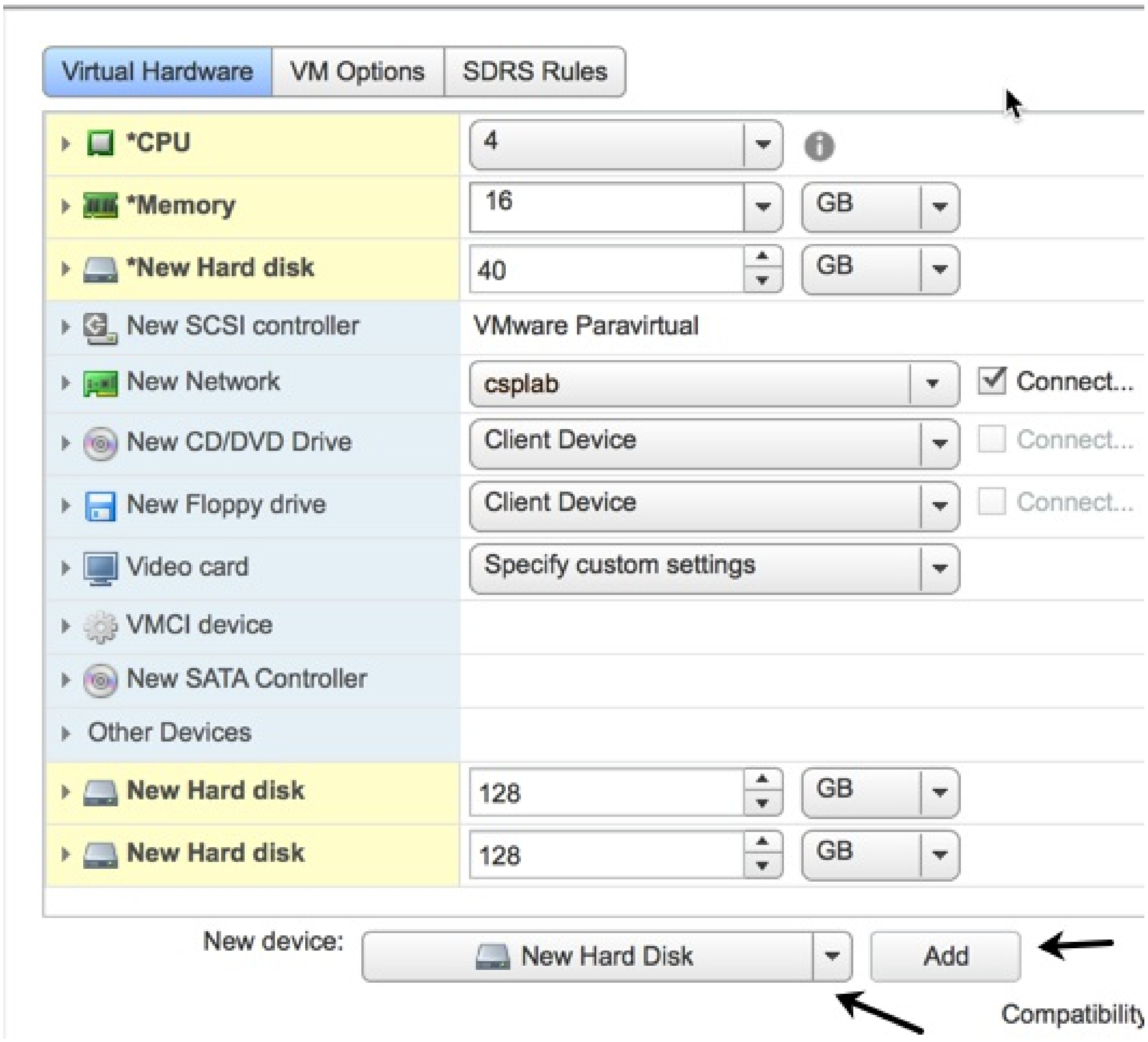
The instructions in this section describe how to run Gluster from a docker container. Other approaches run Gluster "natively".

NOTE: It is recommended that the GlusterFS server cluster be created prior to the actual installation of ICP. You may choose to incorporate a GlusterFS cluster after ICP is installed.

A sample resource configuration for the GlusterFS VMs is summarized in the table below.

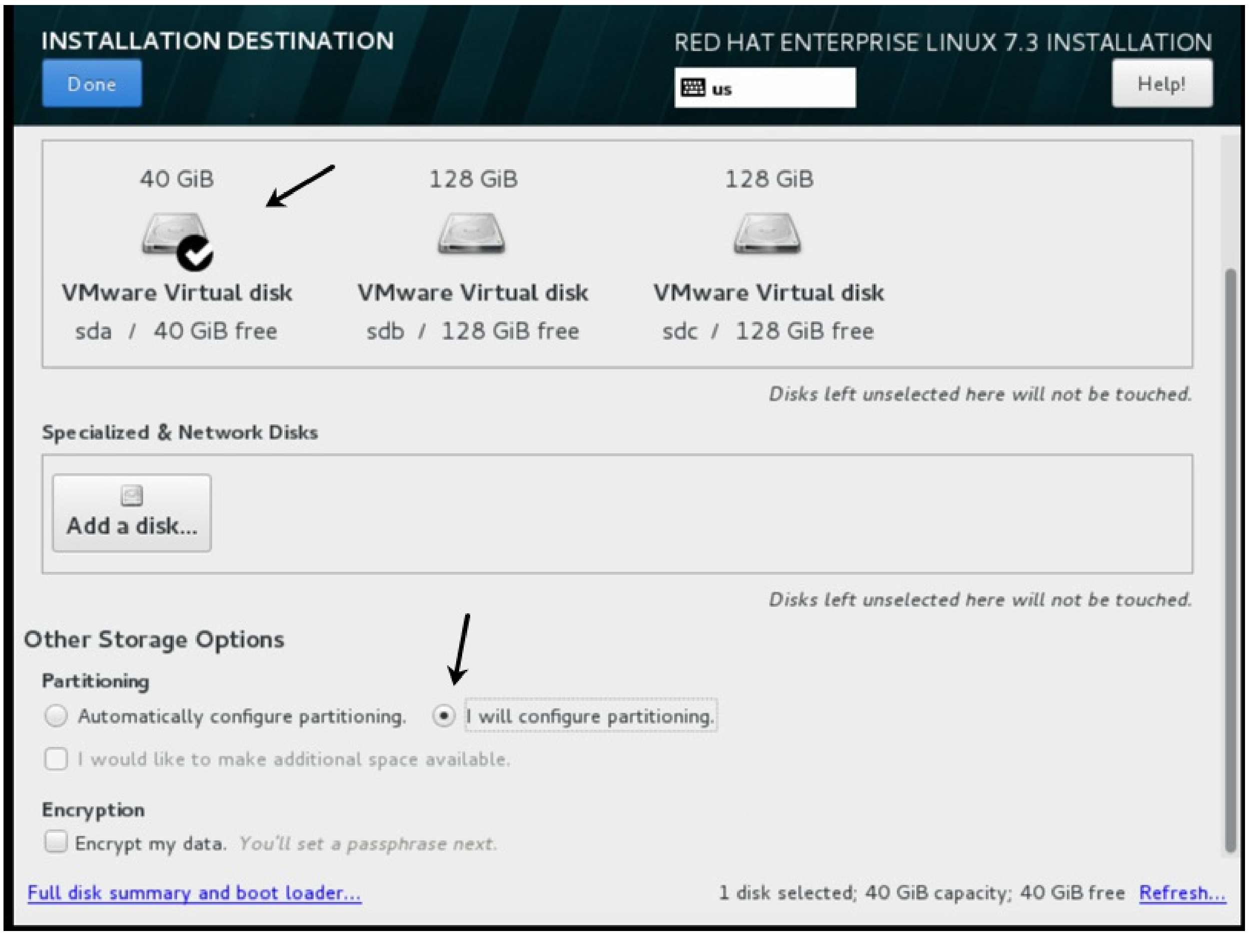
Machine Role	**Number**	**vCPU/Core**	**Memory (GB)**	**Storage Disks x Size (GB)**
GlusterFS	3+	4	16	1 x 40 (/dev/sda) 1 x 128 (/dev/sdb) 1 x 128 (/dev/sdc)

- During the VM creation using vCenter, you can add disks when you get to the "machine settings" screen. At the bottom of the screen there is a "New devices" pull-down menu. Select "Hard disk" and click the add button. (See figure below.)



*CPU	4		
*Memory	16	GB	
*New Hard disk	40	GB	
New SCSI controller	VMware Paravirtual		
New Network	csplab		✓ Connect...
New CD/DVD Drive	Client Device		Connect...
New Floppy drive	Client Device		Connect...
Video card	Specify custom settings		
VMCI device			
New SATA Controller			
Other Devices			
New Hard disk	128	GB	
New Hard disk	128	GB	

New device: New Hard Disk


INSTALLATION DESTINATION

RED HAT ENTERPRISE LINUX 7.3 INSTALLATION

40 GiB	128 GiB	128 GiB
VMware Virtual disk	VMware Virtual disk	VMware Virtual disk
sda / 40 GiB free	sdb / 128 GiB free	sdc / 128 GiB free

Disks left unselected here will not be touched.

Specialized & Network Disks

Disks left unselected here will not be touched.

Other Storage Options

Partitioning

Automatically configure partitioning. [✓ I will configure partitioning.]

I would like to make additional space available.

Encryption

Encrypt my data. *You'll set a passphrase next.*

1 disk selected; 40 GiB capacity; 40 GiB free

- The GlusterFS disks can be thin provisioned.
- You can add disks to an already deployed VM from the vCenter console by opening the "Machine Settings" dialog and adding the disks as described above.
- Only the system disk needs to be partitioned. Heketi will do all the configuration of the storage drives.

The following table is a summary of the system disk partitioning on a GlusterFS server.

File System Name	Mount Point	Size (GB)
system (aka root)	/	32
boot	/boot	256 MB
swap		8

NOTE: The remainder of these instructions assume that Ansible is set up on an administrator machine or some machine that can be used for running Ansible command lines. The Ansible hosts file is assumed to have a group defined named "gluster" with the GlusterFS servers in it.

In the example Ansible command lines, the default Ansible hosts file in `/etc/ansible/hosts` is used. You may prefer to create a hosts file and pass its path in on the command line with the -i option.

NOTE: It is assumed the user running Ansible has passwordless sudo root privileges on the GlusterFS servers.

NOTE: In the Ansible commands the -b and --become options are synonyms. Usually the module or shell command to be executed requires that the user privileges become elevated to root.

NOTE: The simplest instructions assume the GlusterFS server VMs have public Internet access to get to the site where Docker can pull the latest GlusterFS image. If that is not the case, we provide alternate steps that assume only that the Ansible control machine has access to the public Internet.

On each GlusterFS server in the GlusterFS cluster:

- Set up yum repository for RHEL
- Update RHEL
- Install NTP, start and enable NTPD
- Install yum-utils (if you want to use yum-config-manager)
- Install bind-utils
- Install Docker, start and enable Docker
- Stop, disable firewalld
- Create an "Ansible user", e.g., icpmaestro and include that user in the wheel group.
- Modify the /etc/sudoers file (`visudo`) to allow the wheel group sudo any command without password.
- Install the latest version of GlusterFS

```
ansible gluster -b -m shell -a "docker pull gluster/gluster-centos:latest"
```

If the GlusterFS VMs cannot get directly to the public Internet, then the following steps can be used to install GlusterFS. We're assuming your Ansible control machine has Docker installed on it.

- Pull the latest Gluster image on the Ansible control machine; save it; and push it to the GlusterFS server nodes using Ansible. (This step is a substitute for the previous step when the GlusterFS server VMs do not have access to the public Internet.)

```
docker pull gluster/gluster-centos:latest
docker save gluster/gluster-centos:latest | gzip -c > gluster-centos.tar.gz
ansible gluster -b -m copy -a 'src=gluster-centos.tar.gz dest=/tmp/gluster-centos.t
ansible gluster -b -m shell -a 'tar -xf /tmp/gluster-centos.tar.gz' -O | docker loa
```

- To check that the gluster image got loaded:

```
$ ansible gluster -b -m shell -a 'docker images'
```

- Create a `/var/lib/heketi` directory on the GlusterFS machines. Gluster mounts are to be persisted in `/var/lib/heketi/fstab` on each host.

```
$ ansible gluster -b -m file -a 'path=/var/lib/heketi state=directory'
```

- Start docker in privileged mode running gluster. (Most of the command below is bind mounting container "volumes" to host directories.) (For details on options used in the docker run command below, see Docker documentation: docker container run)

```
$ ansible gluster -b -m shell -a 'docker run --restart always -v /etc/glusterfs:/et
```

- To check that gluster is running on each GlusterFS machine, you can use the following command:

```
$ ansible gluster -b -m shell -a 'docker ps -a'
```

NOTE: For information about working with RHEL 7 kernel modules see the Red Hat documentation section Working with Kernel Modules

- Configure kernel to use the `dm_thin_pool` module. (The `dm_thin_pool` module supports LVM thin provisioning. Kernel modules to be loaded at startup are listed in `*.conf` files in `/etc/modules-load.d`.)

```
ansible gluster -m shell -a 'modprobe dm_thin_pool' --become
ansible gluster -m shell -a 'echo dm_thin_pool | tee -a /etc/modules-load.d/modules
```

If you want to check that dm_thin_pool got loaded in the docker image repository:

```
$ ansible gluster -b -m shell -a 'lsmod | grep dm_thin_pool'
gluster03.yyy.zzz | SUCCESS | rc=0 >>
dm_thin_pool           65565  0
dm_persistent_data     67216  1 dm_thin_pool
dm_bio_prison          15907  1 dm_thin_pool
dm_mod                114430  11 dm_log,dm_persistent_data,dm_mirror,dm_bufio,dm_th

gluster01.yyy.zzz | SUCCESS | rc=0 >>
dm_thin_pool           65565  0
dm_persistent_data     67216  1 dm_thin_pool
dm_bio_prison          15907  1 dm_thin_pool
dm_mod                114430  11 dm_log,dm_persistent_data,dm_mirror,dm_bufio,dm_th

gluster02.yyy.zzz | SUCCESS | rc=0 >>
dm_thin_pool           65565  0
dm_persistent_data     67216  1 dm_thin_pool
dm_bio_prison          15907  1 dm_thin_pool
dm_mod                114430  11 dm_log,dm_persistent_data,dm_mirror,dm_bufio,dm_th
```

At this point, the GlusterFS server cluster is up and running and you can proceed with the ICP installation. (*TBD:* There are more steps needed to allocate storage for the ICP master node shared file systems before doing the actual ICP installation.)

Install "native" GlusterFS server

This section describes the steps to installing the GlusterFS server directly on RHEL (not in a container).

If you are using the GlusterFS server installed in a Docker container, (obviously) this section must be skipped.

NOTE: The Gluster server topology and storage volumes do not need to be configured manually. In a later section the hekeit-cli is used to configure the server topology based on a YAML configuration file. The heketi-cli can then be used to define mountable storage volumes. Many sources you find on the Internet describe extensive manual steps to configure storage devices and volumes. You can ignore/skip all those configuration instructions. The Gluster server machines need only to have raw disk devices defined on them.

Installing GlusterFS server on RHEL rather than in a container may be a matter of preference and your level of comfort with containers vs native processes. This section is for those who are more comfortable with working native RHEL processes.

- A yum repository needs to be configured to get the GlusterFS, and Heketi RPMs. Here is a sample yum `gluster.repo` file that needs to be created in `/etc/yum.repos.d/`.

```
[Gluster_4.0]
name=Gluster 3.13
baseurl=http://mirror.centos.org/centos/7/storage/$basearch/gluster-4.0/
gpgcheck=0
enabled=1
```

NOTE: Go out to http://mirror.centos.org/ and walk down the `centos` and `storage` directory tree to find out the latest `gluster` release and update the `gluster.repo` `baseurl` accordingly.

- Disable SE-Linux enforcement (*TBD:* I'm not convinced this is necessary. Gluster doc does not indicate this is necessary. Need to test installing and running with `SELINUX=enforcing`.)

    - Edit /etc/selinux/config and set `SELINUX=disabled`
    - Reboot (`shutdown -r now`)

- Configure `dm_thin_pool` kernel module

```
> modprobe dm_thin_pool
```

- Configure a `dm_thin_pool` in a conf file in `/etc/modules-load.d/` to support setting it at machine reboot. (The files in `/etc/modules-load.d/` are used to configure the kernel when the machine boots.)

```
> echo dm_thin_pool >> /etc/modules-load.d/dm_thin_pool.conf
```

- Install glusterfs-server

```
> yum -y install glusterfs-server
```

- Enable and start the `glusterd` daemon.

```
> systemctl enable --now glusterd
```

- Configure passwordless ssh for root among the GlusterFS servers in the cluster. (This is a multi-way configuration. Each server needs to be able to ssh to the other servers in the cluster.) (*TBD* Add the detail of the commands.)

- Configure firewalld to open gluster server ports (*TBD* For now, stop,disable firewalld. See the Gluster Doc on ports that need to be open.)

Install "native" GlusterFS client

NOTE: Ansible playbook to do this: `icp_install_glusterfs_client.yml` with supporting file `dm_thin_pool.conf`.

See GlusterFS documentation for client installation: Accessing Data: Setting up GlusterFS Clients

Install Heketi on RHEL (aka "native" install)

This section describes the installation of Heketi on RHEL. Heketi and the Heketi client will be running directly on the VM rather than in Kubernetes pods.

See Managing Volumes using Heketi for Red Hat documentation on the Heketi installation and configuration.

- A yum repository needs to be configured to get the GlusterFS, and Heketi RPMs. Here is a sample yum `glusterfs.repo` file that needs to be created in `/etc/yum.repos.d/`.

```
[Gluster_4.0]
name=Gluster 3.13
baseurl=http://mirror.centos.org/centos/7/storage/$basearch/gluster-4.0/
gpgcheck=0
enabled=1
```

- It is assumed a yum repo has been configured that points to a GlusterFS repository.
- Install Heketi server and Heketi CLI

```
> yum -y install heketi
> yum -y install heketi-client
```

- Confirm that port 8080 is not already in use. (`netstat -an | grep 8080`) The heketi server uses port 8080 by default, but that can be changed in the `/etc/heketi/heketi.json` configuration file. (If you run the heketi server on an ICP master node, you will need to use a port other than 8080 since the ICP admin console process uses 8080.)

- Make sure the command line options on the `ExecStart` property in `/usr/lib/systemd/system/heketi.service` use double-dash (--) rather than a single dash (-). It is likely the only option will be `--config`.

- Set up passwordless `ssh` between the heketi server node and all of the gluster server nodes for the gluster cluster to be managed.

```
> ssh-keygen -b 4096 -t rsa -f /etc/heketi/heketi_key -N ""
> ssh-copy-id -i /etc/heketi/heketi_key.pub root@gluster##.xxx.yyy
```

where gluster##.xxx.yyy represents each of the VMs in your gluster server cluster.

- Change the owner and group of the heketi keys to heketi. (The heketi user got created as part of the heketi install.)

```
> chown heketi:heketi /etc/heketi/heketi_key*
```

- Modify the `/etc/heketi/heketi.json` file for your installation.
    - Things to check in particular:
    - port: something not already in use
    - use_auth: true
    - admin key
    - user key
    - executor: ssh
    - sshexec:
        - keyfile: `/etc/heketi/heketi_key`
        - user: root
        - port: 22
        - fstab: `/etc/fstab`
    - The kubeexec section can be ignored since sshexec is being used.
    - The heketi database is in the default location `/var/lib/heketi/heketi.db`.
    - The remainder of the options can be left at the defaults.

- Enable and start the heketi server.

```
> systemctl enable --now heketi
```

- Smoke test for heketi server:

```
> curl http://localhost:8080/hello
Hello from Heketi
```

In the above URL, you will need to use the port you configured for the Heketi server.

NOTE: This native install of Heketi has a single point of failure in the `heketi.db` being located on the node where it gets installed. *TBD:* Revisit this to create a `heketi-db` shared volume in GlusterFS after the initial installation of Heketi. Stop Heketi. Move the `heketi.db` file out of `/var/lib/heketi` to some temporary location. Mount the heketi-db shared volume on `/var/lib/heketi` and copy the existing `heketi.db` into the shared volume. Heketi can then be installed on the other master nodes with that same shared volume mounted on `/var/lib/heketi`. Only one heketi server an be running at any given time to avoid issues with multiple servers accessing the `heketi.db` file concurrently. Hence, running the Heketi server in a Kubernetes pod is a stronger approach.

Things that can go wrong with the Heketi install

unknown shorthand flag: 'c'

With Heketi 4.0.0, the service wouild fail to start. The error in `/var/log/messages` was:

```
Error: unknown shorthand flag: 'c' in -config=/etc/heketi/heketi.json
pvs-master01 heketi: unknown shorthand flag: 'c' in -config=/etc/heketi/heketi.json
```

There is nothing actually wrong with the heketi.json. (You can paste the content into a JSON validator to convince yourself.)

The problem is the -config option to the Heketi executable.

See https://bugzilla.redhat.com/show_bug.cgi?id=1439120

You need to edit the `/usr/lib/systemd/system/heketi.service` file and change the `-config` to `--config`.

Creating the GlusterFS topology using the native heketi-cli.

- Create a topology.json file that represents your GlusterFS server cluster.

NOTE: The GlusterFS documentation and other sources indicate the "manage" attribute for each hostname dictionary should be a fully qualified host name and the storage attribute for each host name should be an IP address. *TBD:* Whether that is actually a strict requirement has not been fully confirmed. Some deployments have shown that using IP addresses for both attributes also appears to work.

Here is a sample topology.json for a 3 server cluster.

```
{
  "clusters": [
    {
      "nodes": [
        {
          "node": {
            "hostnames": {
              "manage": [
                "gluster01.yyy.zzz"
              ],
              "storage": [
                "172.16.20.15"
              ]
            },
            "zone": 1
          },
          "devices": [
            "/dev/sdb",
            "/dev/sdc"
          ]
        },
        {
          "node": {
            "hostnames": {
              "manage": [
                "gluster02.yyy.zzz"
              ],
              "storage": [
                "172.16.20.16"
              ]
            },
            "zone": 1
          },
          "devices": [
            "/dev/sdb",
            "/dev/sdc"
          ]
        },
        {
          "node": {
            "hostnames": {
              "manage": [
                "gluster03.yyy.zzz"
              ],
              "storage": [
                "172.16.20.17"
              ]
            },
            "zone": 1
          },
          "devices": [
            "/dev/sdb",
            "/dev/sdc"
          ]
        }
      ]
    }
  ]
}
```

If you tend to fat-finger JSON files, it is a good idea to run the `topology.json` content through a JSON validator. (It is easy to incorrectly edit JSON syntax.) Search the Internet for a JSON validator to your liking.

To get general usage help with the heketi-cli, use `heketi-cli --help`.

To get more specific help use `heketi-cli command --help` where `command` is one of the heketi-cli commands. (The "commands" are not verbs but rather an object type or class, e.g., topology, cluster, volume, node and device.)

To get specific help for the "commands" associated with a given object type use `heketi-cli type command --help`, for example `heketi-cli topology load --help`.

When working with heketi-cli it is very convenient to export values for the following environment variables:

```
> export HEKETI_CLI_SERVER=http://localhost:8081
> export HEKETI_CLI_USER=admin
> export HEKETI_CLI_KEY=passw0rd
```

NOTE: When providing the Heketi server URL, be sure not to include a trailing slash on the URL. So for example `http://localhost:8081/` will lead to problems. The trailing slash causes an issue for a volume create operation, for example.

The above example assumes the Heketi server is listening on port 8081 rather than the default port 8080. The port the Heketi server is using is defined in the heketi.json. In the above, the user and key are based on what is defined in the heketi.json that you configured before starting the Heketi server.

- Use the heketi-cli to load the topology.json file.

```
> heketi-cli topology load --json=topology.json
```

Obviously, the above command is assumed to have been run from the directory where the topology.json file is located.

Once the topology has successfully loaded you can use `heketi-cli topology info` to see information about the topology.

At this point you are ready to create mountable volumes that can be used by the ICP master nodes for shared storage.

Things that can go wrong with Heketi CLI

Error: Unable to get topology information: Unknown user

This is caused by not having a --user argument or HEKETI_CLI_USER set.

Error: Unable to get topology information: signature is invalid

This error may occur when you run:

```
heketi-cli topology load --json=topology.json
```

The above assumes the `topology.json` file is in the current directory.

The "signature" in question has nothing to do with the content of the `topology.json` file or some digital signature it might be missing.

When you run an heketi-cli command, and you have JWT authentication enabled (see your `heketi.json`), you need to provide a user and "key" (aka password or secret). One way to provide the key is to set the environment variable, HEKETI_CLI_KEY. You can also pass it in on the `heketi-cli` command line with the `--secret` option. (See `heketi-cli --help` usage info.)

If the password/secret you provide does not match up with the user and key in the heketi.json file in current use by the Heketi service, then you will get the "signature is invalid" error.

NOTE: If you change anything in the `heketi.json` file you need to restart the Heketi service (`systemctl restart heketi`) to pick up the changes.

Install Heketi administration client for Gluster in Kubernetes

NOTE: The installation of Heketi in Kubernetes is very confusing. This section is currently under review and should be taken as a collection of notes rather than verified guidance.

If you are not using GlusterFS for the shared file service, this section can be skipped.

If you installed Heketi directly on RHEL, then (obviously) this section can be skipped.

This section describes the steps to install the Heketi administration client for GlusterFS in a Docker container managed by Kubernetes. Another option is to do a "native" Heketi installation. See [Install Heketi on RHEL (aka "native" install)](#Install Heketi on RHEL (aka "native" install)).

Public Heketi install guide: Heketi Install for Kubernetes

The Heketi client is installed on the boot-master machine. (A Heketi client can be installed where you prefer, including on an administrator's desktop machine. The Heketi client obviously must have network access to the Gluster servers to be managed.)

- Follow the instructions for the Heketi install. (Ignore the GlusterFS installation instructions. The GlusterFS install was done into docker containers on each of the GlusterFS servers. (See above section of this guide.) Important to note that the glusterfs install uses Docker only, not Kubernetes. *TBD:* Should we create a separate Kubernetes cluster for GlusterFS? That seems like overkill. I would do a "native" GlusterFS install instead.)

- Get the Heketi CLI for the current release. (*TBD:* The instructions mention that this has heketi-cli in it. However, it is vague as to what it means to "install" the heketi-cli. I'm not sure what it is used for.)

- Extract the archive on the machine where you are doing the installation. (Create a heketi directory in /root on master01 and extracted the archive there. `tar -xvf heketi-client-v5.0.1.linux.amd64.tar.gz`. The root of everything in the archive is `heketi-client`, so no need to create a separate directory where the archive is extracted.)

- *TBD:* Also cloned the heketi git hub. There appears to be more useful content in the git repo than what comes with the release tar ball. (The following clone command was executed from the /root/heketi staging directory.) Is this a reasonable step or unnecessary? Or should this be done instead of downloading and extracting the heketi tar ball? The heketi release tar ball has the heketi-cli executable in it. But I'm not sure what that is used for.

```
git clone https://github.com/heketi/heketi heketi-git-hub
```

- Create a kubernetes service account.

```
kubectl create -f heketi-client/share/heketi/kubernetes/heketi-service-account.json
```

- Create a cluster role binding for the service account so it can administer the gluster servers.

```
kubectl create clusterrolebinding heketi-gluster-admin --clusterrole=edit --service
```

- Create kubernetes secret:

```
kubectl create secret generic master01-root-ssh-key --from-file=/root/.ssh/id_rsa
```

TDB: What/where does this secret get used? Looks like it should be referenced in the heketi.json config file, but I'm not sure how yet. That's where the heketi executor is set and in this case `ssh` should be used for the executor.

- Make a copy of the `heketi.json` to edit for the install. (*TBD:* There are a number of `heketi.json` files in the git repo. I started with the one in `<repo-clone>/etc/heketi.json`)

- Things that may need to be changed in `heketi.json`:

  - Server port: 8081 (8080 is used by the ICP console.)

  - use_auth: True

  - admin key, user key (*TBD:* Are these two secrets a password? Or the name of a kubernetes secret? Looks like they are supposed to be a password.)

  - glusterfs executor: ssh

  - user: root (*TBD:* Likely need to create a separate heketi user rather than use root.)

  - key file: /root/.ssh/id_rsa

  - fstab: (*TBD* Not sure what to use here. On the gluster server nodes we created a `/var/lib/heketi/` where `fstab` is intended to go. So for now, use `/var/lib/heketi/fstab`.)

  - kubernetes exec (kubeexec)

    - host: https::8443
    - cert: don't care (*TBD:* What would this be in a more realistic configuration.)
    - insecure: true (*TBD:* Should be false in a realistic deployment.)
    - user: admin
    - password: admin
    - namespace: default (*TBD:* Not sure what this should be. Maybe `service`)
    - fstab: `/var/lib/heketi/fstab` (*TBD:* Need to confirm this is the correct path.)
    - auto_create_block_hosting_volume: false (*TBD:* Confirm this is correct. I'm pretty sure we don't want this.)
    - block_hosting_volume_size: 100 (in GB)
    - The next step in the heketi install guide is to create a secret based on the heketi.json. (*TBD:* Not really sure what it means to use that whole config file to create a "secret". How is that secret used?)

```
kubectl create secret generic heketi-config-secret --from-file=./heketi.json
```

- Make a copy of `heketi-bootstrap.json` that comes in the `<repo-clone>/extras/kubernetes/`
- Edit the `heketi-bootstrap.json` file to make sure it is what you want.
    - Originally I had replicas set at 2. But then realized that for the heketi bootrap service, likely I only need 1 replica.
    - I changed all the port 8080 to 8081. (*TBD:* Need to confirm.)
    - There is an env var HEKETI_EXECUTOR that I changed to `ssh` from `kubernetes`.
    - The names of some other things are in this file. They match the names used in earlier commands. If different names are used, then corresponding changes would need to be made in this file.
- Then do the following:

```
kubectl create -f heketi-bootstrap.json
```

- The first run of the heketi-bootstrap create failed. Below is the event list from `kubectl describe pods`:

```
Events:
  Type     Reason                  Age               From                    Message
  ----     ------                  ----              ----                    -------
  Normal   Scheduled               4m                default-scheduler       Success
  Normal   SuccessfulMountVolume   4m                kubelet, 172.16.249.84  MountVo
  Normal   SuccessfulMountVolume   4m                kubelet, 172.16.249.84  MountVo
  Normal   SuccessfulMountVolume   4m                kubelet, 172.16.249.84  MountVo
  Warning  FailedCreatePodSandBox  4m (x7 over 4m)   kubelet, 172.16.249.84  Failed 
  Normal   SandboxChanged          4m (x7 over 4m)   kubelet, 172.16.249.84  Pod san
  Warning  FailedSync              4m (x8 over 4m)   kubelet, 172.16.249.84  Error s
```

- To delete things you need to do the following:
  - Delete the heketi deployment: `kubectl delete deployment deploy-heketi`
  - Deleting the service as well: `kubectl delete service deploy-heketi`
  - NOTE: Deleting the deployment, deletes the pod(s), but it doesn't delete the service. (*TBD:* Not sure why deleting a deployment does not delete the service.)

- Second try with only 1 replica.

```
kubectl create -f heketi-bootstrap.json
```

Create persistent volumes for ICP master node shared file systems

This section applies to an HA ICP deployment where there are 3 or 5 master nodes. If you are doing a simple sandbox installation with a single master node, this section can be skipped.

NOTE: The heketi-cli commands in this section assume that the following environment variables have been set appropriately:

- HEKETI_CLI_SERVER

- HEKETI_CLI_USER

- HEKETI_CLI_KEY

- Get the glusterfs cluster ID. The topology info will have the cluster ID.

```
heketi-cli topology info
```

NOTE: The heketi doc recommends not providing a name for the created persistent volumes. That is debatable. If you have a good naming convention that ensures uniqueness, then using a descriptive name seems like a good idea rather than using the default names that are generated strings which have no descriptive value.)

- Create a volume for the master audit log. In this example a 10GB volume is created.

```
> heketi-cli volume create --size=10 --clusters=042e3eb4b386b086c17d9d947e8ba885
10GiB volume created for use by master nodes for shared audit log (mounted at /var/
Name: vol_de785f066ce0e0ce86c39c5fb920682c
Size: 10
Volume Id: de785f066ce0e0ce86c39c5fb920682c
Cluster Id: 042e3eb4b386b086c17d9d947e8ba885
Mount: 172.16.20.17:vol_de785f066ce0e0ce86c39c5fb920682c
Mount Options: backup-volfile-servers=172.16.20.15,172.16.20.16
Durability Type: replicate
Distributed+Replica: 3
```

- Make note of the mountable volume host and name. That is what is used in the mount command and the entry in `/etc/fstab` on each of the master nodes. In the above example it is: `172.16.20.17:vol_de785f066ce0e0ce86c39c5fb920682c` You can replace the IP address with an actual hostname if you have an entry in DNS or `/etc/hosts` on the master nodes for the GlusterFS servers.

- Mount the volume on each master node (Note the colon used to separate the backup servers rather than a comma.)

```
> mount -t glusterfs -o backup-volfile-servers=gluster01.xxx.yyy:gluster02.yyy.zzz
```

- Add a line to `/etc/fstab` (*TBD:* Does the backup-volfile-servers option work in fstab?)

```
gluster03.xxx.yyy:vol_de785f066ce0e0ce86c39c5fb920682c /var/lib/icp/audit glusterfs
```

- Create a volume for the master docker registry. In this example a 50GB volume is created.

```
> heketi-cli volume create --size=50 --clusters=042e3eb4b386b086c17d9d947e8ba885
Name: vol_ccdb21cfd1e83cf9c3299207f66fb705
Size: 50
Volume Id: ccdb21cfd1e83cf9c3299207f66fb705
Cluster Id: 042e3eb4b386b086c17d9d947e8ba885
Mount: 172.16.20.17:vol_ccdb21cfd1e83cf9c3299207f66fb705
Mount Options: backup-volfile-servers=172.16.20.15,172.16.20.16
Durability Type: replicate
Distributed+Replica: 3
```

- Mount the volume on each master node (Note the colon used to separate the backup servers rather than a comma.)

```
> mount -t glusterfs -o backup-volfile-servers=gluster01.xxx.yyy:gluster02.yyy.zzz
```

- Add a line to `/etc/fstab` (*TBD:* Does the backup-volfile-servers option work in fstab?)

```
gluster03.xxx.yyy:vol_ccdb21cfd1e83cf9c3299207f66fb705 /var/lib/registry glusterfs
```

Install IBM Cloud Private v2.1

This is the start of the description of the steps to install IBM Cloud Private.

Prerequisite steps to Install IBM Cloud Private v2.1

1. If you are building your own VM, you should have already created a clone of the ICP base VM for each VM in the cluster. At a minimum, this would be the boot-master, the proxy and a couple of worker nodes.

2. If you are using VMs provided to you, then you should have completed all the steps to getting Docker running on at least the boot-master machine. The install process includes installing Docker on each cluster member. As an expedient we recommend pre-installing Docker on each cluster member. (See the section [Copy and load ICP docker image tar ball to all cluster VMs](#Copy and load ICP docker image tar ball to all cluster VMs) below for details.)

3. DNS or the `/etc/hosts` file on each VM should be configured with the proper entries so that each VM can resolve the address of the other members of the cluster/cloud.

4. SSH needs to have been set up such that the "boot master" VM can ssh to each of the other VMs in the cluster/cloud as root without using a password.

5. The product install image should be available on the boot-master machine. If not, download the product archives from Passport Advantage (IBM customer) or eXtreme Leverage (IBM internal). You can find the GA release by searching on, *IBM Cloud Private*.

6. The ICP Knowledge Center (KC) installation instructions for ICP Cloud Private Enterprise are rooted in the section: Intalling ICP Cloud Private Enterprise.

7. On all VMs in the ICP cluster, if firewalld is running, stop it and disable it until after the ICP install completes.

To see if firewalld is running, use:

```
> systemctl status firewalld
```

To stop and disable firewalld, use:

```
> systemctl stop firewalld
> systemctl disable firewalld
Removed symlink /etc/systemd/system/dbus-org.fedoraproject.FirewallD1.service.
Removed symlink /etc/systemd/system/basic.target.wants/firewalld.service.
```

NOTE: The firewall only needs to be disabled during install. It gets enabled again on all members of the cluster/cloud after the install has completed.

NOTE If you are creating an ICP cluster with VMs (members) on more than one network segment/VLAN, then there may be physical firewalls that need to be configured to allow the ICP installation to proceed. See the ICP Knowledge Center section, Default ports, for the list of ports that must be open for installation and configuration of an ICP instance.

Some additional "boot master" pre-installation steps

This section has some steps that need to be taken on the boot master before the actual installation command can be run.

NOTE: In these instructions, the root directory of the installation is referred to as `<ICP_HOME>`. A common convention is to install ICP in a directory that includes the ICP version in the directory name, e.g., `/opt/icp2101`.

- It is assumed that Docker is installed and running on the boot-master machine.
- It is assumed that the ICP images archive has been loaded into the Docker registry on the boot-master machine. (*NOTE:* The actual archive file name may be different depending on the version of ICP you are installing.)

```
tar -xf ibm-cloud-private-x86_64-2.1.0.1.tar.gz -O | docker load
```

- (On the boot-master) Extract the ICP boot meta-data to the `<ICP_HOME>/cluster` directory:

```
> cd <ICP_HOME>
> docker run -v $(pwd):/data -e LICENSE=accept ibmcom/icp-inception:2.1.0.1-ee cp -
```

NOTE: You may need to using a different version tag for the `icp-inception` image. Use `docker images | grep icp-inception` to see the version tag in your image repository.

The above command creates a directory named `cluster` in `<ICP_HOME>`. The `cluster` directory has the following contents:

```
> ls -l cluster
  -rw-r--r--. 1 root root 3998 Oct 30 06:37 config.yaml
  -rw-r--r--. 1 root root   88 Oct 30 06:37 hosts
  drwxr-xr-x. 4 root root   39 Oct 30 06:37 misc
  -r--------. 1 root root    1 Oct 30 06:37 ssh_key
```

- Add the IP address of all the cluster/cloud members to the `hosts` file in `<ICP_HOME>/cluster`.

  NOTE: The ICP hosts file must use IP addresses. Host names are not used.

- Copy the ssh key file to the /cluster. (This overwrites the empty ssh_key file already there.)

```
> cp ~/.ssh/id_rsa ssh_key
cp: overwrite ‘ssh_key’? y
```

- Check the permissions on the ssh_key file and make sure they are read-only for the owner (root). If necessary, change the permissions on the ssh_key file in `<ICP_HOME>/cluster` to "read-only" by owner, i.e., root.

- Check the access:

```
> ls -l ssh_key
  -r--------. 1 root root 1675 Jun 30 13:46 ssh_key
```

- If the access is not read-only by owner, then change it:

```
> chmod 400 ssh_key
```

- Check again to make sure you changed it correctly.

- Copy/move the "image" archive (`ibm-cloud-private-x86_64-2.1.0.1.tar.gz`) to the images directory in `<ICP_HOME>/cluster`. (You first need to create the images directory.) In the command below it is assumed the image archive is located initially in `<ICP_HOME>`.

From `<ICP_HOME>/cluster`:

```
> mkdir images
> mv `<ICP_HOME>/ibm-cloud-private-x86_64-2.1.0.1.tar.gz` images
```

Working with the config.yaml file is described in the next section.

Configuring `config.yaml` on the boot master

For information on the content of `config.yaml`, see the ICP KC section, Cluster configuration settings.

For a simple sandbox deployment, the content of `config.yaml` can remain as is.

NOTE: The network_cidr and service_cluster_ip_range are set to "10." IP networks. If your cloud provide is using that same address range, then change the values to something else, e.g., some other "10." subnet or the "172.16." networks.

Things that can be left as-is for a small sandbox environment:

- network_type calico
- network_cidr: 10.1.0.0/16
- service_cluster_ip_range: 10.0.0.1/24
- For a simple cluster, everything else in `config.yaml` remains commented out.

There are many parameters that may be set in `config.yaml`. It is a good idea to read through the file to become familiar with the options.

Additional things that need to be set for a production environment:

- vip_iface, cluster_vip
- proxy_vip_iface, proxy_vip

You may want to include a `version` attribute in `config.yaml`. I if you do, be sure it matches the version of the images in the docker registry that you want to use. You can do a `docker images` list to check the version tags of the available images. The version that will be deployed is set to an appropriate default in a YAML file in the icp-inception container so it setting the `version` value in `config.yaml` is intended for cases where the docker registry being used contains images from more than one version.

Likewise, you may want to include a `backup_version` attribute value in the `config.yaml`. Again, make sure the value of `backup_version` makes sense for the docker registry in use in that it matches the tag on the images that are intended to be the backup version.

NOTE: Gluster configuration in config.yml is not necessary when the Gluster servers are set up outside the ICP cluster, which is the topology used in this guide. **Do not** do any Gluster configuration in `config.yaml`.

Other things that you may need to check

This section has a collection of items that have led to a failure in the installation process. This is a work in progress and is a place to keep track of this sort of stuff that seems a bit random.

- Make sure all the VMs in the cluster/cloud are running.

You may want to double check the following on each VM that is a member of the cluster:

- The network interface on each VM is started.
- The firewall on each VM is disabled.
- If you pre-installed Docker on each VM, then check that Docker is running on each VM.
- Docker must be installed and running on the boot-master VM.
- The ICP docker images must be loaded into the Docker registry on the boot-master VM.

Copy and load ICP Docker images tar ball to all cluster VMs

This section assumes that Docker is pre-installed on all of the cluster member VMs. Installing Docker on each VM uses the same steps as installing Docker on the boot-master VM.

NOTE: The need to do this step will likely go away with ICP releases starting with v2.1.0.2. The icp-inception process will configure a docker hub on the boot/master and the other nodes will pull images from it as needed. The local docker hub approach will make the image deployment process significantly more efficient.

It is expedient to pre-load the Docker registry on each VM that is a member of the ICP cluster. The installation process run from the boot-master machine will recognize that the Docker registry is up-to-date on the other cluster member machines and skip the step of copying and loading the image tar ball to the Docker registry on the given machine. The gain in the time it takes to load the registry is achieved because you can open as many shells as needed to do the copy and load operations concurrently.

- Copy the ICP image tar ball to all machines. (You can open multiple shells on the boot-master machine and start an `scp` of the image tar ball to each machine in the cluster.)

- Open a shell on each VM in the cluster and extract the docker images and load them into the docker registry:

```
tar -xvf ibm-cloud-private-x86_64-2.1.0-beta-2.tar.gz -O | docker load
```

If you run out of file system space during the above command, use `df -h` to view file system utilization. You can use `df -ih` to view inode utilization. Make sure the file systems are adequately provisioned as described in the [Check the file system sizing](#Check the file system sizing) section above.

- On all but the boot-master machine, the ICP image tar file can be removed once the docker load completes. On the boot-master machine the ICP image tar file gets moved to an images directory in `<ICP_HOME>/cluster`.

NOTE: If you are building an ICP virtual machine, you can run the extract and load on the base VM image so that all cloned VMs have the docker registry pre-loaded with the ICP images.

No space left on device

During the load of the ICP images you may get something like:

```
Error processing tar file(exit status 1): write /opt/ibm/wlp/output/.classCache/C28
```

Do a `df -H` to see what is happening with file space.

Run the ICP install command

Docker is used to run the install for all members of the cluster/cloud. The command is shown below after some introductory notes. (This takes some time depending on the number of machines in the cluster. If you haven't pre-loaded the Docker images used by ICP, the image file gets copied to each VM and the images get loaded as part of the installation.) Run the install from `<ICP_HOME>/cluster` directory.

NOTE: It is assumed Docker is installed on the boot-master VM.

NOTE: It is assumed the ICP v2.1 images have been loaded into the local docker registry on the boot-master VM.

NOTE: In the docker commands below, $(pwd) is the current working directory of the shell where the command is run, i.e. `<ICP_HOME>/cluster`. It is assumed there are no space characters in the current working directory path. (It is a really bad idea to use space characters in directory and file names.) If you happen to have space characters in the current working directory path, then surround the $(pwd) with double quotes.

NOTE: It is OK to run this command multiple times to get things installed on all members of the cluster/cloud should problems show up with a particular cluster/cloud member. At least for basic problems, the error messages are very clear about where the problems are, e.g., network connectivity, firewall issues, docker not running.

NOTE: As of ICP v2.1.0.2, an uninstall is recommended after a failed installation. The installation detects that some lock files are still present if an uninstall has not been done and prompts you to do an uninstall.

NOTE: During the installation all information messages go to stdout/stderr. If you want to capture a log of the installation process, you need to direct output to a file. The docker command line below uses `tee` to capture the log and also allow it to be visible in the shell window. A logs directory in `<ICP_HOME>/cluster>` was created to hold the log files. The log file will have escape character sequences in it for color coding the text output, but it is readable.

```
> cd <ICP_HOME>/cluster
> mkdir logs
> docker run --net=host -t -e LICENSE=accept -v $(pwd):/installer/cluster ibmcom/ic
```

A common convention (not shown here) is to include a date stamp in the file name of the install log that gets written to /tmp (in this case) as well as a log number (in this case 1). The log number can be incremented each time the command is rerun if you want to save each log file.

NOTE: A single `-v` option is recommended to include a useful amount of trace information in the log. If you need to get more detail for installation problem determination purposes add a `-vv` or `-vvv` to the command line after the install verb for progressively more information, e.g.,

```
> docker run -e LICENSE=accept --net=host --rm -t -v $(pwd):/installer/cluster ibmc
```

- When the install completes, you want to see all "ok" and no "failed" in the recap. (The play recap sample below is from a sandbox deployment. A production cluster will obviously have a lot more machines listed.)

```
PLAY RECAP *********************************************************************
xxx.xx.xxx.50              : ok=109  changed=36   unreachable=0    failed=0
xxx.xx.xxx.52              : ok=109  changed=36   unreachable=0    failed=0
xxx.xx.xxx.57              : ok=137  changed=36   unreachable=0    failed=0
xxx.xx.xxx.60              : ok=163  changed=55   unreachable=0    failed=0
```

```
localhost                    : ok=216   changed=114   unreachable=0    failed=0
```

- Problem determination is based on the installation log. The error messages are relatively clear. If the recap contains a non-zero failed count for any of the cluster members or something is unreachable, then grep/search the install log for `FAIL` or `fatal` to begin the problem determination process.

- Assuming the install went correctly move on to some basic "smoke tests" described in the section below.

- Once the installation completes successfully and you have performed some basic tests, the firewall on each cluster member will need to be configured to open ports as described in the ICP Knowledge Center section, Default ports. Port 8443 on the master needs to be open to get to the ICP console.

Start and enable the firewalld on all cluster members

You may want to hold off on this step until some basic smoke tests have been executed. See the [Simple ICP smoke tests](#Simple ICP "smoke" tests) section below.

After the install completes, configure firewall rules on each cluster member according to the ICP Knowledge Center section, Default ports.. Then start and enable firewalld on each cluster/cloud member.

Simple ICP "smoke" tests

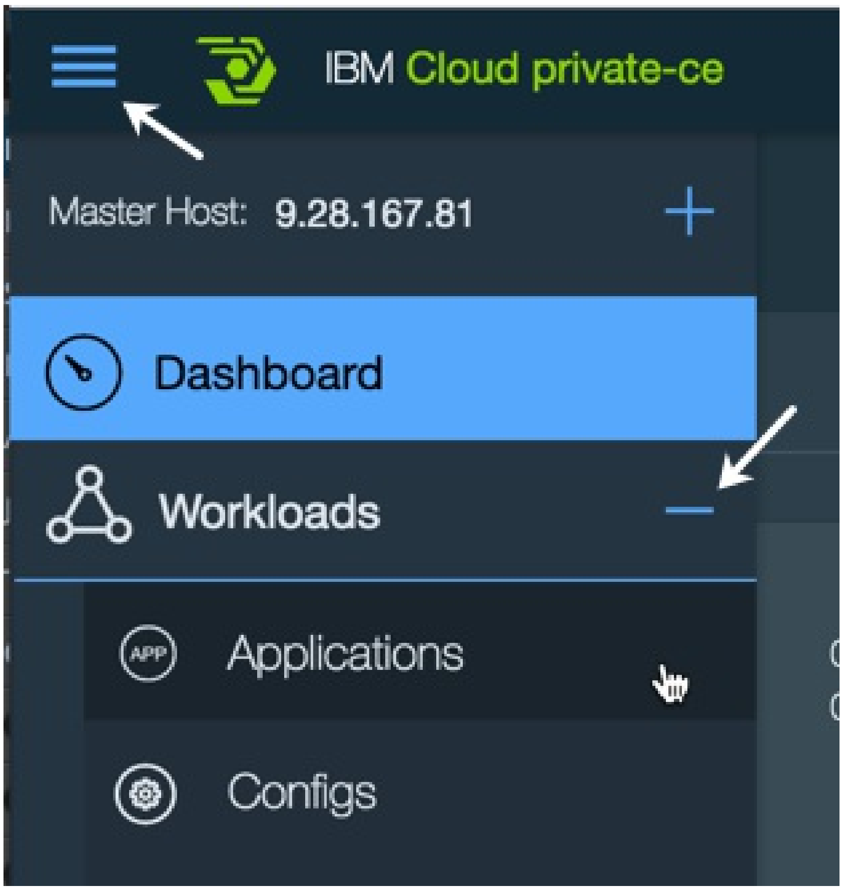
This section documents some basic measures to confirm correct ICP operation.

1. The simplest "smoke test" is to fire up the ICP admin console:

```
https://<boot_master>:8443/
```

Default user ID and password: admin/admin

2. Check that all processes are "available". In the ICP admin console you can see the workloads via the "hamburger" menu in the upper left corner margin. (See figure below.)



Troubleshooting installation issues

This section is a holding area for a collection of troubleshooting tips.

1. Install using the `-vvv` and piping output to tee to a log file is the first step. Examine the log file for the first sign of an error. Attempt the same command manually as the log indicates is having a problem to try to get to root cause.

2. Make sure the docker images repository has the correct images in it. For example, kubernetes-ee may not be present. Or the wrong version of kubernetes or some other image is in the docker images registry/repository.

Configure a Kubernetes StorageClass

In order to use the shared storage provided by the GlusterFS cluster, some additional Kubernetes artifacts need to be created. The ICP cluster needs to be up and running in order to create these artifacts.

NOTE: It appears that you need to be logged in as admin to the Kubernetes/ICP cluster to work with Storage Classes.

Create a secret for Heketi admin

Kubernetes documentation on secrets

The Heketi admin secret holds the admin user and password defined in the `/etc/heketi/heketi.json` file used to configure the Heketi server. The secret is needed to create a Kubernetes Storage Class as described in the next sub-section.

The user and key attributes must be base64 encoded. The `base64` utility is handy for encoding and decoding strings.

NOTE: Make sure you use the -n option to echo so that the string to be encoded does not include a newline character.

```
> echo -n passw0rd | base64
cGFzc3cwcmQ=
```

```
> echo -n admin | base64
YWRtaW4=
```

Here is a sample YAML for a secret named `heketi-secret` defined in the default namespace. (Be careful about proper indenting if you cut-and-paste to a file.)

```
---
apiVersion: v1
type: kubernetes.io/glusterfs
kind: Secret
metadata:
  name: heketi-secret
  namespace: default
data:
  user: YWRtaW4=
  key: cGFzc3cwcmQ=
```

Assuming the above content is in a file named `heketi-secret.yml`, the command to create the secret:

```
kubectl create -f heketi-secret.yml
```

Create a storage class for persistent volume claims

Kubernetes Storage Class documentation
Kubernetes Persistent Volume and Persistent Volume Claim documentation

When a Persistent Volume Claim (PVC) is made in Kubernetes, a Storage Class (SC) is needed to satisfy the claim.

To create a storage class you need:

1. The GlusterFS cluster ID of the GlusterFS cluster to be used.
2. The URL that points to the Heketi server to be used to manage the storage. (If the Heketi server is running in a Kubernetes pod, then the host name (FQDN) or IP address will be the proxy server virtual host name or VIP.)
3. The name and namespace of the Kubernetes secret that holds the Heketi server admin user and password.
4. Other optional configuration parameters. (It is best to err on the side of explicitly defining attributes rather than relying on default values.)

The following YAML can be used to create a storage class named cluster.shared.storage in the default namespace. (Be careful about proper indenting if you cut-and-paste to a file.)

```yaml
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: cluster.shared.storage
provisioner: kubernetes.io/glusterfs
parameters:
  resturl: "http://172.16.25.100:8081"
  clusterid: "042e3eb4b386b086c17d9d947e8ba885"
  restuser: "admin"
  secretNamespace: "default"
  secretName: "heketi-secret"
  volumetype: "replicate:3"
```

WARNING: Be very careful not to include a trailing slash on the `resturl` for the Heketi server. For example, `http://172.16.25.100:8081/` will fail when you use the storage class to create a PVC with a cryptic error message. The storage class will fail when creating a volume. The state of the PVC will be "pending". You can see the error in the "events" associated with the PVC.

Assuming the above content is in a file named `cluster-shared-storage.yml`, the command to create the storage class:

```
> kubectl create -f cluster-shared-storage.yml
```

At least one StorageClass object should be set as the `default`. To make the `cluster.shared.storage` the default StorageClass use the following command:

```
> kubectl patch storageclass cluster.shared.storage -p '{"metadata": {"annotations"
```

Once the storage class is created and made the default, confirm that it works by created a test PVC using `kubectl` or the ICP console.

Uninstall IBM Cloud Private

This section describes the steps to uninstalling ICP. You may need to do this if things go wrong and you want to do a clean install.

```
> docker run -e LICENSE=accept --net=host --rm --name=installer -t -v $(pwd):/insta
```

The following directories should not exist on any nodes in the cluster/cloud:

```
/var/lib/etcd/
/var/lib/kubelet/
/etc/cfc/
```

NOTE: When you are using an HA configuration you will have multiple master nodes using a shared volume mounted at `/var/lib/registry`. You will probably need to unmount that volume on each master node (`umount /var/lib/registry`). (*TBD:* It doesn't seem to be the case that `/var/lib/icp/audit` needs to be unmounted.)

Install Ansible

Ansible is very useful for administration of a collection of machines such as an ICP cluster. We recommend installing it to ease general administration of the ICP cluster.

See the Ansible documentation for installation instructions. The installation instructions are very detailed and complete for virtually every platform.

Your RHEL yum repository is likely to have the Ansible RPM in the "extras" directory.

If you have access to the public Internet you can get Ansible RPMs via yum, here: https://releases.ansible.com/ansible/rpm/release/epel-7-x86_64/.

To add the public Ansible yum repo do:

```
> yum-config-manager --add-repo https://releases.ansible.com/ansible/rpm/release/ep
```

The above command should add a repo to `/etc/yum.repos.d/` that will be named something like: `releases.ansible.com_ansible_rpm_release_epel-7-x86_64_.repo`

```
> ls /etc/yum.repos.d/
docker-ce.repo  redhat.repo  releases.ansible.com_ansible_rpm_release_epel-7-x86_64
```

Yum will not access the public Ansible repository unless you install its public key. The public key did not appear to be available anywhere obvious at the Ansible releases site. The simple thing to do is edit the repo file and set `gpgcheck=0`.

```
[releases.ansible.com_ansible_rpm_release_epel-7-x86_64_]
name=added from: https://releases.ansible.com/ansible/rpm/release/epel-7-x86_64/
baseurl=https://releases.ansible.com/ansible/rpm/release/epel-7-x86_64/
gpgcheck=0
enabled=1
```

Do the Ansible installation:

```
> yum -y install ansible
```

Configuring Ansible

This section describes some very basic steps required to get Ansible configured to the point where you can start to do things with it.

The Ansible documentation is very good. Use it to find answers to your questions. The Getting Started describes what you need to do to get started. The Introduction to Ad-Hoc Commands provides a quick overview on running ad hoc commands through Ansible.

Some things to decide when using Ansible:

- The machine (or machines) to be an Ansible "control machine", e.g., administrator desktop, a "staging" or "jump" server, the ICP "boot" server. See the Ansible documentation for Control Machine Requirements. If you use your ICP boot server (boot/master0) as an Ansible control server, it already has things set up for root to be able to run Ansible commands to all other nodes in the ICP cluster.
- What user to set up on the control machine(s) and all of the managed nodes that will be used by Ansible to access the managed nodes via SSH using SSH keys. It is recommended (but not required) that the SSH authentication use keys. (We refer to this user as the "*Ansible user*".) The Ansible user needs to be able to use sudo without providing a password to run commands that require root privileges.

The primary configuration tasks:

- Make sure each managed node has the Ansible user ID defined. The Ansible user will need to be able to use passwordless sudo to get root privileges.
- Create an `ssh` key for the Ansible user on the control machine.
- Use `ssh-copy-id` (or something that does the equivalent) to get the public key (`id_rsa.pub`) of the Ansible user on each Ansible control machine in the SSH `authorized_users` file for the Ansible user on each managed node.
- Set up the Ansible `hosts` (in `/etc/ansible` by default) file to defined the managed nodes.

NOTE: Use fully qualified domain names (FQDN) for the hosts when using the `ssh-copy-id` command or whatever you use to get the Ansible user's SSH key spread around to the managed nodes. If you use the short host name, you will likely get *The authenticity of host 'myhost.mysite.com (xxx.xxx.x.xx)' can't be established.* errors when you try something even as simple as an Ansible ping. Check the SSH `known_hosts` file for the Ansible user on the Ansible control machine to confirm that that the FQDN, and the IP address is listed with the host key if you are not sure about what will be recognized.

NOTE: A simple way to provide the Ansible user with passwordless sudo privileges to run any command is to add the Ansible user to the wheel group. For RHEL the command, `usermod -a -G wheel <ansible_user>` will add the `<ansible_user>` to the wheel group. You will likely need to edit the `/etc/sudoers` file (using `visudo`) to comment out the default `wheel` entry and uncomment the `NOPASSWD` `wheel` entry. See sample below:

```
## Allows people in group wheel to run all commands
# %wheel        ALL=(ALL)       ALL

## Same thing without a password
%wheel  ALL=(ALL)       NOPASSWD: ALL
```

Docker basics

The following collection of sub-sections is intended to provide enough information about Docker to get you started. The commands described tend to be things that come up frequently in the operation of IBM Cloud Private. Your favorite Internet search engine is your friend when it comes to learning Docker and Docker command idioms.

Getting a list of docker container status

The `docker ps` command is likely one of the first commands you will want to know and you will use it often. You can add the -a option to see all containers, i.e., those that have exited as well as those still running.

```
> docker ps
```

or

```
> docker ps -a
```

use

```
> docker help ps
```

to get more information on ps options.

Getting a list of local docker registry content

It is useful to get a list of what is in the local docker registry. (The term registry is misused by docker. The docker registry is really a repository, i.e., it holds the docker images, not just a list of where the images are located.)

```
docker images
```

Once ICP is loaded into the local docker repository, there are a lot of images. You will likely want to grep for some string that is part of the image of interest to cut down the amount of output from a full docker images list.

Open a shell in a Docker container.

It is assumed the container includes a bash shell. (Every once in awhile you run into one that doesn't.)

```
docker exec -it <container_id>|<container_name> /bin/bash
```

Getting a shell inside the icp-inception container

The command below will open a shell console in a container for the given docker image. (You will need to use an appropriate image name for the local docker registry.)

```
> docker run -e LICENSE=accept --net=host --rm -it -v "$(pwd)":/installer/cluster -
```

Delete docker containers using an image with a given tag

When you get a list of all containers (running and terminated) using `docker ps -a`, the first column is the container ID, which is the primary argument to `docker rm`, that removes a container.

You may find that you need to remove all containers using a particular image (with a particular tag) in order to remove the image from the local docker registry.

```
> docker rm $(docker ps -a | grep 2.1.0.2-rc2-ee | awk '{print $1}')
```

Delete images from the local Docker registry with a given tag

In order to free up file system space you may want to delete a bunch of images with a given tag. In the example images associated with a particular ICP release are deleted.

When you get a list of docker images using `docker images`, the third column is the image ID, which is the primary argument to `docker image rm`.

```
> docker image rm $(docker images | grep 2.1.0.2-rc1 | awk '{print $3}')
```

Kubernetes in a nutshell

The following collection of sub-sections is intended to provide enough information about kubernetes to get you started. Obviously, to become proficient with kubernetes, you will need to gain experience through use and you will need to consult more complete sources of information, including the kubernetes documentation.

Installing kubectl on the ICP boot-master node

Copying kubectl from a container to the host /usr/local/bin
It is very useful to be able to have kubectl available at the shell on the ICP boot-master or boot machine.

You can get kubectl from the kubernetes container already installed as part of ICP. (*NOTE:* In the command sample below you may need to modify the version tag on kubernetes. Use `docker images | grep kubernetes` to see your actual version tag for kubernetes.)

```
> docker run --net=host -v /usr/local/bin:/data ibmcom/kubernetes:v1.8.3-ee cp /kub
```

Kubernetes basics

The command line tool for working with Kubernetes is `kubectl`.

Kubernetes Getting Started

A quick source of kubectl help: Kubernetes kubectl "cheat sheet"

When working with kubectl you need to be authenticated in your shell. Authentication involves a number of steps.

To set up authentication in your shell:

1. Log into the ICP console. The client setup command stream is available under the user name in the upper right margin of the ICP console.
2. Click on the user name, then click on "Configure client" and in the pop-up window, click on the copy icon next to the "kubectl config" commands in the pop-up window.
3. Do a paste in the shell window you are using. At that point, the shell is configured to properly use `kubectl` commands.

The authentication token is good for 12 hours. You have to log out of the ICP console and log back in to get a new token using the same procedure described in the steps above.

You can see your kubectl context using the `kubectl config view` command.

Get a list of namespaces

```
kubectl get namespaces
```

Get a list of pods

```
kubectl get pods --all-namespaces
```

NOTE: A newly deployed ICP cluster typically has pods defined only in the kube-system namespace.

You can limit the pod listing to a specific namespace with the `--namespace=NAMESPACE_NAME`, e.g.,

```
kubectl get pods --namesapce=kube-system
```

NOTE: If you want to see the terminated pods, i.e., those that have completed or errored out, then use the `-a (--show-all)` option with the `get` command.

Get info about a pod

```
kubectl describe pod <pod_name>
```

The describe command is particularly useful on any of the different kinds of Kubernetes objects.

Get a list of deployments

```
kubectl get deployments
```

Get a log associated with a pod or container

```
kubectl logs pod/<pod_name> | tee -a mypod.log
```

or

```
kubectl logs pod/<pod_name> --container=<container_name> | tee -a mycontainer.log
```

If a pod has more than one container in it, then you need the `--container (-c)` option.

Check out the usage information for the logs command (`kubectl logs --help`) for details on all the options.

Combining kubectl commands

You can use all the usual Linux idioms for combining commands with `kubectl`.

Here is an example of deleting a bunch of pods with `bluecompute-ce` in the pod name:

```
kubectl delete pods $(kubectl get pods -a | grep bluecompute-ce | awk '{print $1}')
```

Change the current namespace preference

Typically the namespace associated with a given kubeconfig will be the default namespace. However you can change it to some other namespace.

The following command changes the currently preferred namespace to `kube-system`. By doing so the `--namespace` option for `kubectl` commands is not needed if the namespace if interest is `kube-system`.

```
kubectl config set-context $(kubectl config current-context) --namespace kube-syste
```

For more detailed information on Kubernetes namespaces, see the Kubernetes Namespaces documentation.

`kubectl` without logging in

There may be times when you can get the "client config" command line content from the ICP console, but you still want to be able to use `kubectl`. In those cases get on the one of the master nodes (with kubectl installed) and use `-s localhost:8888` as one of the command line options to `kubectl` followed by the command you want to run.

For example:

```
> kubectl -s localhost:8888 --namespace=kube-system get pods
```

Helm basics

It is useful to have Helm installed somewhere convenient. Helm can be used to install applications that are described by Helm charts. Helm is the client for a server named Tiller. ICP includes a Tiller server running in a pod.

NOTE: Be careful about working with a version of Helm that is more recent than the version of Tiller deployed in ICP. It is recommended that you install the version of Helm that matches the version of Tiller.

Helm is often installed on the boot/master01 node of the ICP cluster. Another recommended place to install Helm is on the workstation of the cluster administrator(s).

Instructions for installing helm are available in github. See Installing Helm

The "From Script" approach works well for RHEL nodes. Access to the public Internet is a requirement for running the script. There are other options for an air-gap installation.

It is a good idea to be logged into the ICP cluster at the time Helm is installed (or at least when `helm init` is run) as the Helm initialization process checks for a Kubernetes context and determines if Tiller installed is and running in the cluster.

In general, when working with Helm, you need to be logged into a Kubernetes cluster in order to connect to the Tiller server. (For example, `helm version` will provide the version of Helm, but then fail to connect to the Tiller server if you don't have a Kubernetes context established.)

Install Python Docker support

This section describes the steps for installing Python Docker support modules. The Docker modules that get installed allow all the usual Docker commands to be used within a Python script.

NOTE: This section may be skipped. Installing the Python Docker support modules is optional. If you don't intend to use Python for scripting of Docker operations, then this section can be skipped. It is **not** necessary to install pip as a pre-requisite to installing ICP.

NOTE: Python has a `docker` package and a `docker-py` package. The documentation gives the impression they are synonymous. However, in comparing the effects of doing the install of docker vs docker-py, they do not appear to be equivalent. The installation of the `docker` package appears to include the `docker-py` package, but not vice versa. More investigation is needed.

In order to install the Python Docker support modules, pip needs to be installed. (Pip is the Python package manager.) In order to install pip, the python-setuptools package needs to be installed.

- Install Python setup tools. (Python setuptools may already be installed.)
  `yum -y install python-setuptools Loaded plugins: langpacks, product-id, search-disabled-repos, subscription-manager Package python-setuptools-0.9.8-4.el7.noarch already installed and latest version Nothing to do`

- Install pip.

  ```
  easy_install pip
  Searching for pip
  Reading https://pypi.python.org/simple/pip/
  Best match: pip 9.0.1
  ...
  Adding pip 9.0.1 to easy-install.pth file
  Installing pip script to /usr/bin
  Installing pip2.7 script to /usr/bin
  Installing pip2 script to /usr/bin

  Installed /usr/lib/python2.7/site-packages/pip-9.0.1-py2.7.egg
  Processing dependencies for pip
  Finished processing dependencies for pip
  ```

- Install Python Docker support modules.

  ```
  pip install docker
  ```

After the install of the Python Docker support modules you should see the following directories:

```
> ls -l /usr/lib/python2.7/site-packages/docker*
/usr/lib/python2.7/site-packages/docker:
api   auth.py   client.py   constants.py   errors.py   __init__.py   models      tl
auth  auth.pyc  client.pyc  constants.pyc  errors.pyc  __init__.pyc  ssladapter  tl

/usr/lib/python2.7/site-packages/docker-2.5.1.dist-info:
DESCRIPTION.rst  INSTALLER  METADATA  metadata.json  RECORD  top_level.txt  WHEEL

/usr/lib/python2.7/site-packages/docker_py-1.10.6.dist-info:
DESCRIPTION.rst  INSTALLER  METADATA  metadata.json  RECORD  top_level.txt  WHEEL
```

```
/usr/lib/python2.7/site-packages/dockerpycreds:
constants.py  constants.pyc  errors.py  errors.pyc  __init__.py  __init__.pyc  stor

/usr/lib/python2.7/site-packages/docker_pycreds-0.2.1.dist-info:
DESCRIPTION.rst  INSTALLER  METADATA  metadata.json  RECORD  top_level.txt  WHEEL
```

Things that can go wrong with the Python Docker support installation

- Pip needs access to the public Internet to get the modules. Public access to the Internet may not be available in all contexts. In such cases, you need to configure a private pip repo.

RHEL 7 network interface overview

This section describes some basic information about networking for RHEL 7.

RHEL 7 networking is controlled by the Network Manager (network service). Normally the network service will be running and it will be started at boot time.

The usual `systemctl` commands are used for dealing with the network service.

```
systemctl status|start|stop|restart network
```

For example:

```
systemctl status network
network.service - LSB: Bring up/down networking
Loaded: loaded (/etc/rc.d/init.d/network; bad; vendor preset: disabled)
Active: active (exited) since Thu 2017-06-29 16:51:39 EDT; 2 days ago
Docs: man:systemd-sysv-generator(8)
...
```

Even though the network service may be running, that does not mean a particular network interface is running.

To view the status of the network interfaces on a machine (and to get the names of the interfaces) use the `ifconfig` command.

```
ifconfig -a
```

The commands for starting and stopping a network interface are `ifup` (start), `ifdown` (stop). You need to provide the interface name.

For example, suppose the name of the interface is `ens33`.

To stop the ens33 interface:

```
ifdown ens33
Device 'ens33' successfully disconnected.
```

To start the ens33 interface:

```
ifup ens33
Connection successfully activated (D-Bus active path: /org/freedesktop/NetworkManag
```

The `ifup` and `ifdown` commands work through the Network Manager (i.e., the network service).

For a lot more details on RHEL 7 networking see the various sections in the Introduction to Red Hat Enterprise Linux Networking chapter of the RHEL documentation.

RHEL system parameters overview

This section provides some background how system parameters are managed.

RHEL system parameters can be configured in several places with a well-defined precedence. The `/etc/sysctl.conf` file is intended for use by the "local" system administrator. Parameter settings in `/etc/sysctl.conf` have the highest precedence with respect to the value settings. Other locations where system configuration parameters are read in order of precedence are: `/etc/sysctl.d/*.conf`, `/run/sysctl.d/*.conf` and `/usr/lib/sysctl.d/*.conf`. There are other locations for system configuration parameters as well. See the man pages for sysctl and sysctl.d for more details.

NOTE: It is recommended that configuration parameter file names have a leading 2-digit number followed by a dash in order to clearly indicate the ordering in which the files should be processed at the time the machine is booted. (The files are processed in the lexical ordering of their names.)

The following observations apply to a default RHEL image. The specific VM you are using may be configured differently.

- On a default RHEL image, the `/etc/sysctl.conf` file has nothing in it, and comments in `/etc/sysctl.conf` refer to using files in `/usr/lib/sysctl.d`.

- On a default RHEL image, `/usr/lib/sysctl.d` has three files:
  `ls /usr/lib/sysctl.d/ 00-system.conf 50-default.conf 60-libvirtd.conf`

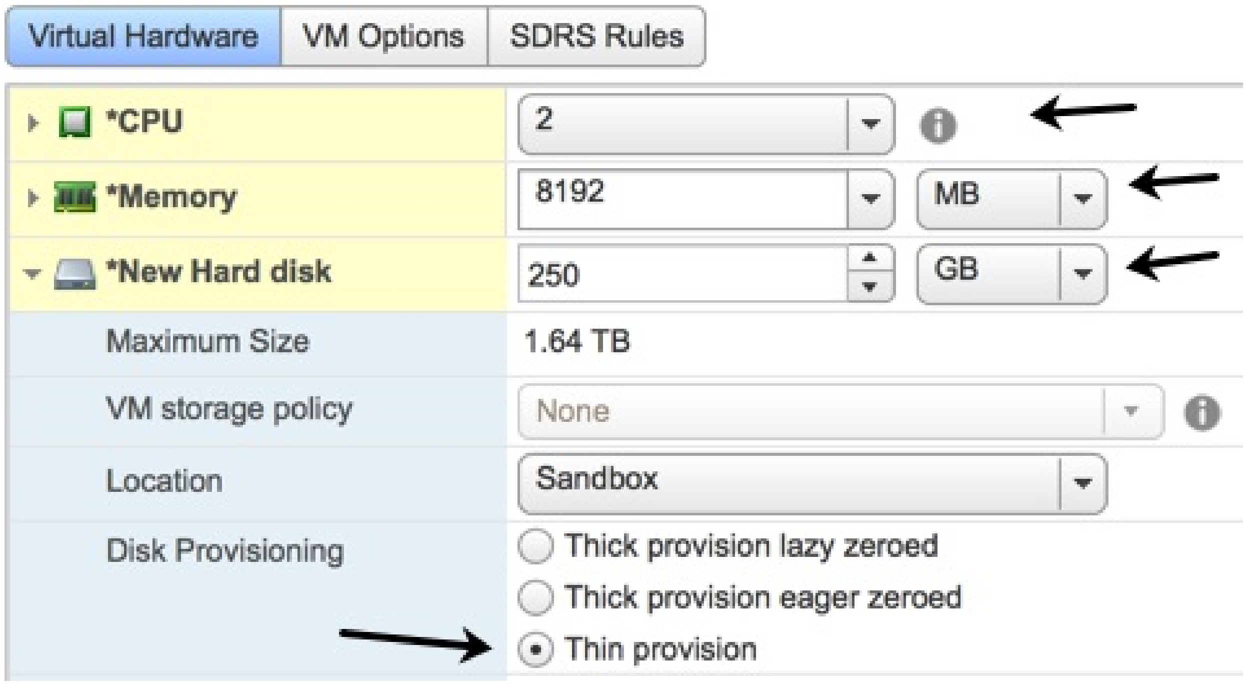
- On a default RHEL image, none of the above files has anything in it having to do with `vm.max_map_count`.

- On a default RHEL image, there is nothing in `/run/sysctl.d/` (The sysctl.d directory does not exist.)
  The `/etc/sysctl.d` has only the file, `99-sysctl.conf`, but that file has nothing in it except the preface comments.

Installing RHEL 7 - a sample

For those of you who may need to build your own VMs, this section provides a step-by-step look at installing RHEL v7 on a VM created in a vCenter cluster. Obviously, some details may be different due to differences in hypervisor or your specific environment. The intent of this section is to provide enough guidance to get you through the RHEL 7 installation process, particularly if you are not an experienced RHEL system administrator.

- In a vCenter console, a VM is initially created in the "Hosts and Clusters" navigation pane. You can right-click on a cluster folder and select "New Virtual Machine…". Follow the bouncing ball from there. You will shortly get to a screen that lets you configure the VMs resources. (See figure below.)

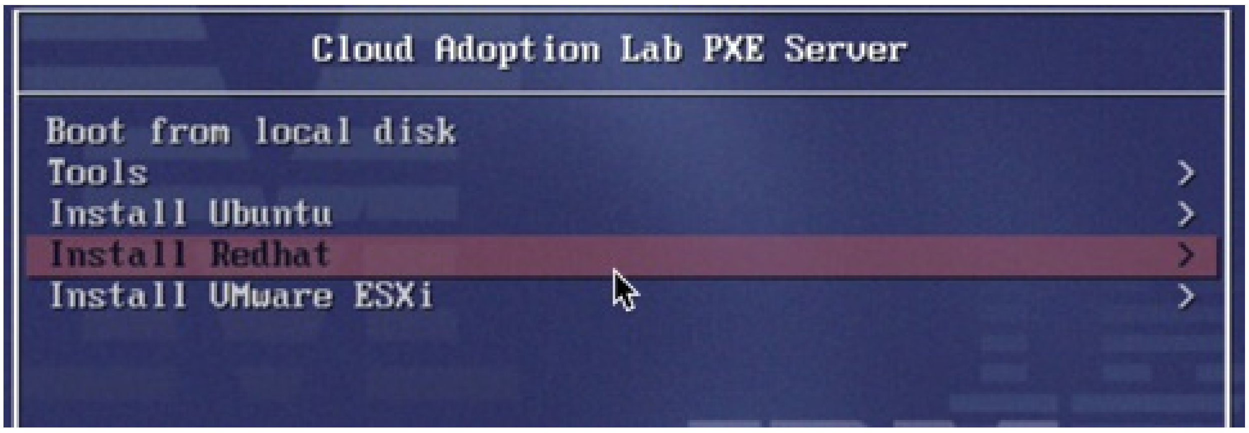

Virtual Hardware | VM Options | SDRS Rules

*CPU	2	
*Memory	8192	MB
*New Hard disk	250	GB
Maximum Size	1.64 TB	
VM storage policy	None	
Location	Sandbox	
Disk Provisioning	Thick provision lazy zeroed / Thick provision eager zeroed / [✓ Thin provision]	

NOTE: A more realistic ICP master node resource allocation is 8 core, 32 GB of memory, 250 GB storage. We used smaller core and memory for this sample deployment. See the resource allocation table in section [A production ICP installation in a nutshell](#A production ICP installation in a nutshell) for suggested production deployment resource allocations for the various ICP machine roles.

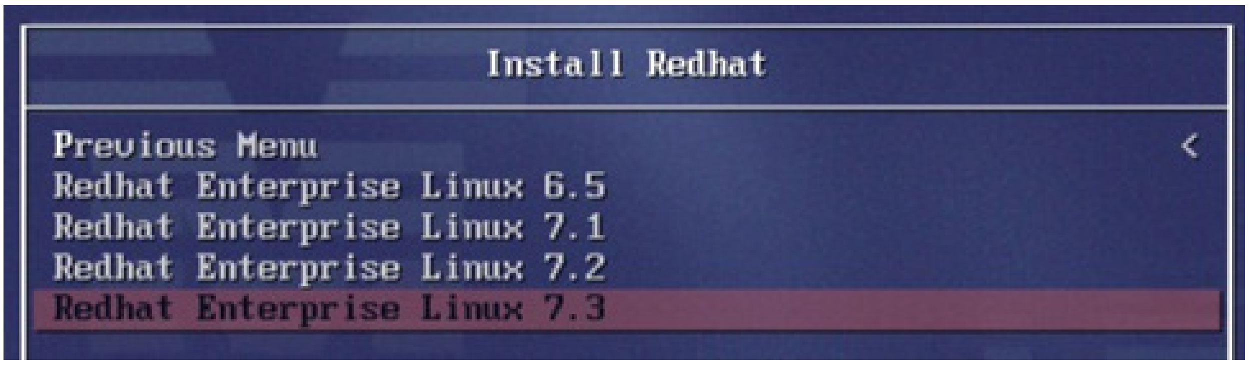
NOTE: When creating VMs in a "cloud" environment, it is usually appropriate to select "thin provisioning" for the disks as shown in the figure above.

- Continue to follow the bouncing ball until you hit finish.
- Power on the VM and right-click on it and select the "Open console" item. Once the console is open you should see something in the console that looks like the figure below.


```
Cloud Adoption Lab PXE Server

Boot from local disk
Tools                                   >
Install Ubuntu                          >
Install Redhat                          >
Install VMware ESXi                     >
```

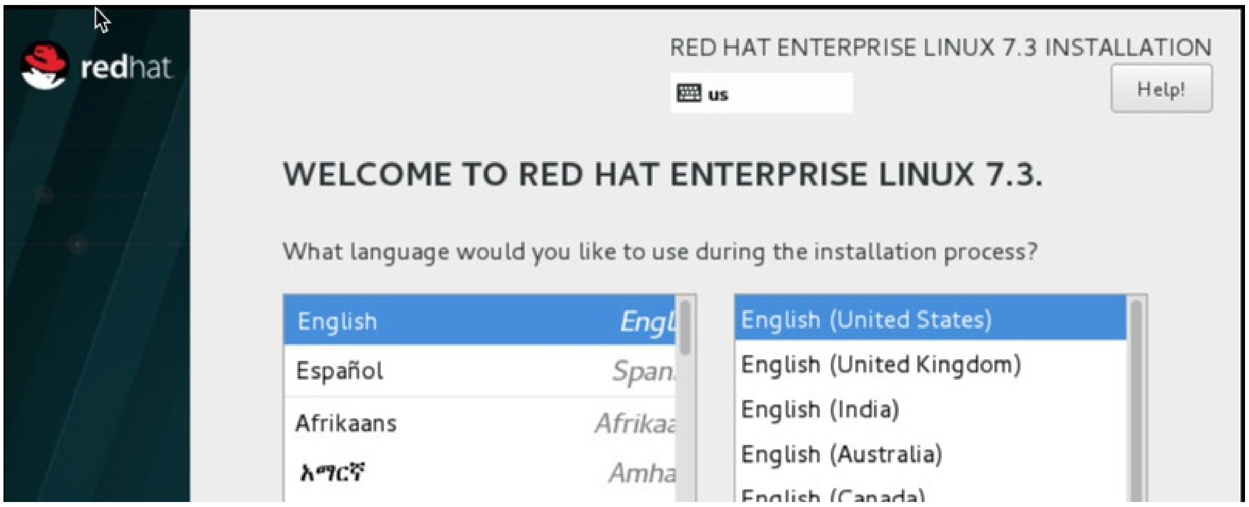
- Choose the most recent version of RHEL available.



```
Install Redhat

Previous Menu                                   <
Redhat Enterprise Linux 6.5
Redhat Enterprise Linux 7.1
Redhat Enterprise Linux 7.2
Redhat Enterprise Linux 7.3
```

- A lot of logging will scroll by on the console as some initial installation steps occur.
- You will be presented with a screen where you can choose the language you want to use. (See figure below.)



RED HAT ENTERPRISE LINUX 7.3 INSTALLATION

us

Help!

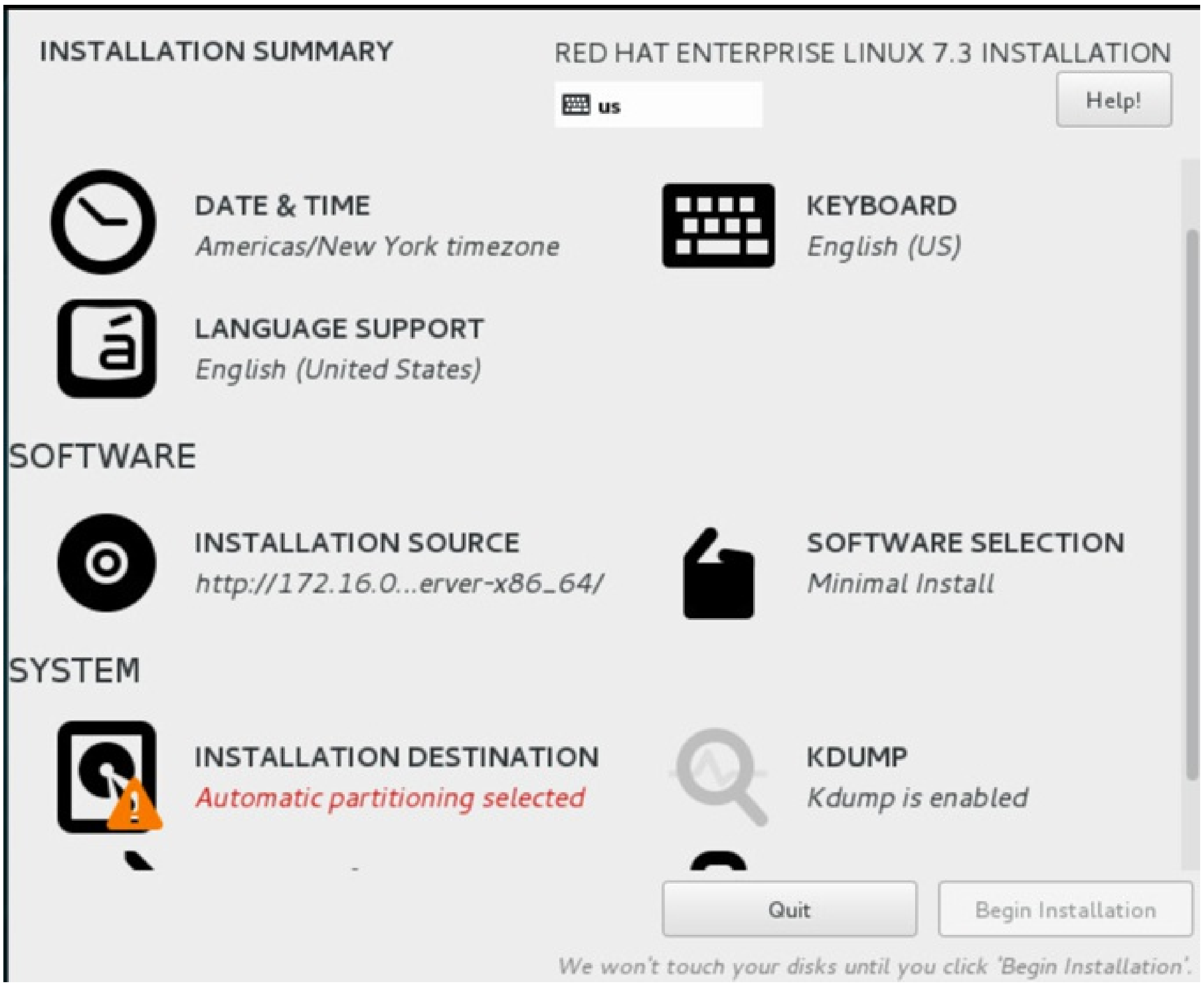
WELCOME TO RED HAT ENTERPRISE LINUX 7.3.

What language would you like to use during the installation process?

English	Engl
Español	Span
Afrikaans	Afrikaa
አማርኛ	Amha

English (United States)
English (United Kingdom)
English (India)
English (Australia)
English (Canada)

- Once you choose the language, click on the Continue button in the lower right corner.
- The next screen is where all the action is. (See figure below) You will likely need to scroll to see all the installation configuration options.


INSTALLATION SUMMARY

RED HAT ENTERPRISE LINUX 7.3 INSTALLATION

us

DATE & TIME
Americas/New York timezone

KEYBOARD
English (US)

LANGUAGE SUPPORT
English (United States)

SOFTWARE

INSTALLATION SOURCE
http://172.16.0...erver-x86_64/

SOFTWARE SELECTION
Minimal Install

SYSTEM

INSTALLATION DESTINATION
Automatic partitioning selected

KDUMP
Kdump is enabled

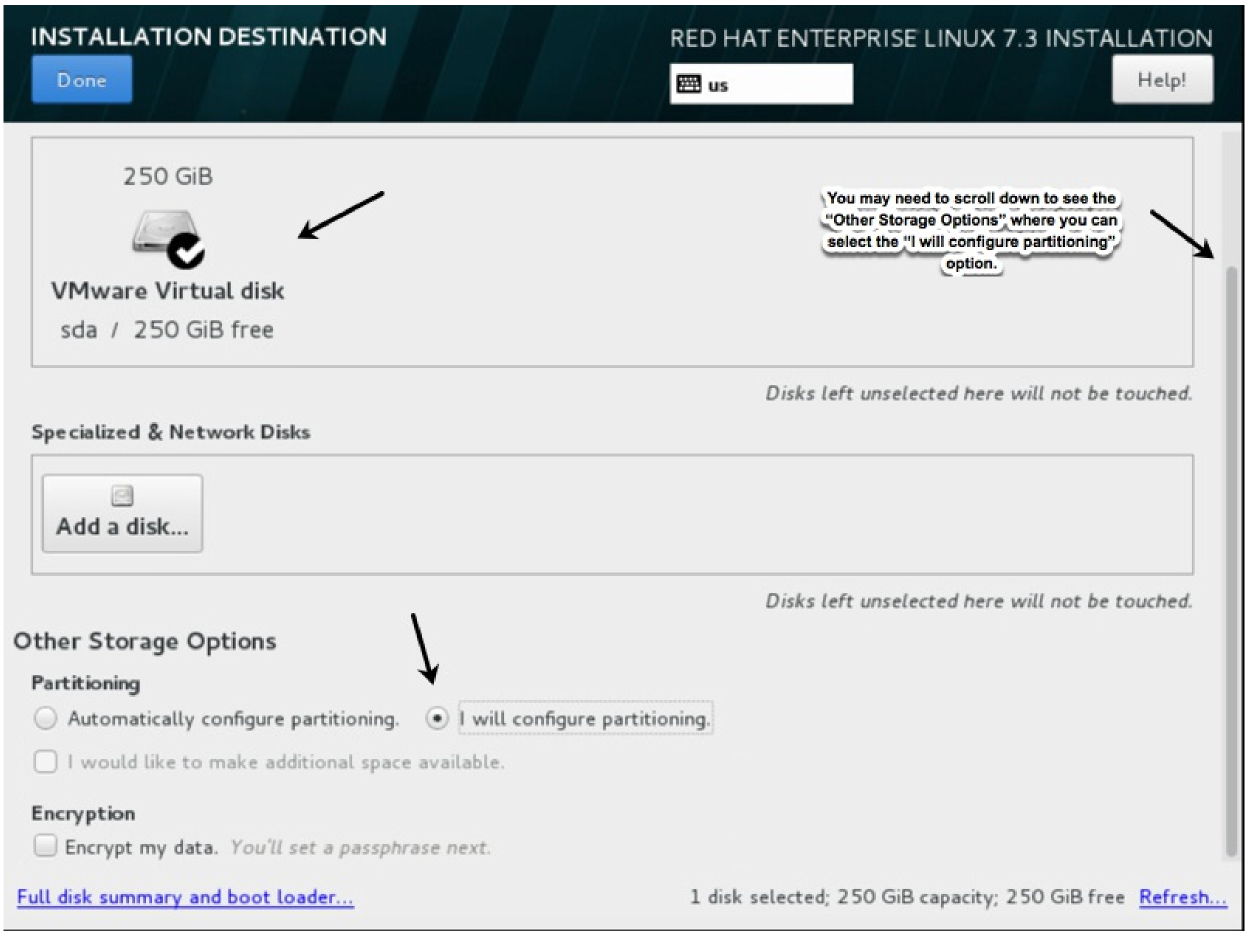
We won't touch your disks until you click 'Begin Installation'.

- Things to take particular note of in this screen are:
  - Software Selection: For an ICP node a "minimal install" is sufficient. Anything else you need can be picked up from a RHEL yum repository. A minimal install keeps the VM small and fast to boot. If you want to look at the other options click on the Software Selection icon.
  - Installation Destination: This is where you configure disk partitions and file system layout. See RHEL 7 documentation section: Installation Destination for guidance on disk partitioning. Consult your operations team for the standard disk partitioning and file system layout used for RHEL images. See the subsection below for steps for laying out the file system partitions.
  - Security Policy: (In this sample, no security profile is selected. Use of the security profiles is currently beyond the scope of this installation guide.)
  - Network and Host Name: You will likely want to choose a non-default host name. Consult your operations team to find out what host naming conventions are used in your data center. This is also where additional NICs can be configured. For this

sample only 1 NIC was configured.

RHEL v7 installation disk partitioning

When you select "Installation Destination" in the installation summary screen, you will see the option, "I will configure partitioning". You may need to scroll down to expose that option. (See figure below.)



INSTALLATION DESTINATION

RED HAT ENTERPRISE LINUX 7.3 INSTALLATION

250 GiB

VMware Virtual disk

sda / 250 GiB free

You may need to scroll down to see the "Other Storage Options" where you can select the "I will configure partitioning" option.

Disks left unselected here will not be touched.

Specialized & Network Disks

Disks left unselected here will not be touched.

Other Storage Options

Partitioning

○ Automatically configure partitioning. [✓ ● I will configure partitioning.]

☐ I would like to make additional space available.

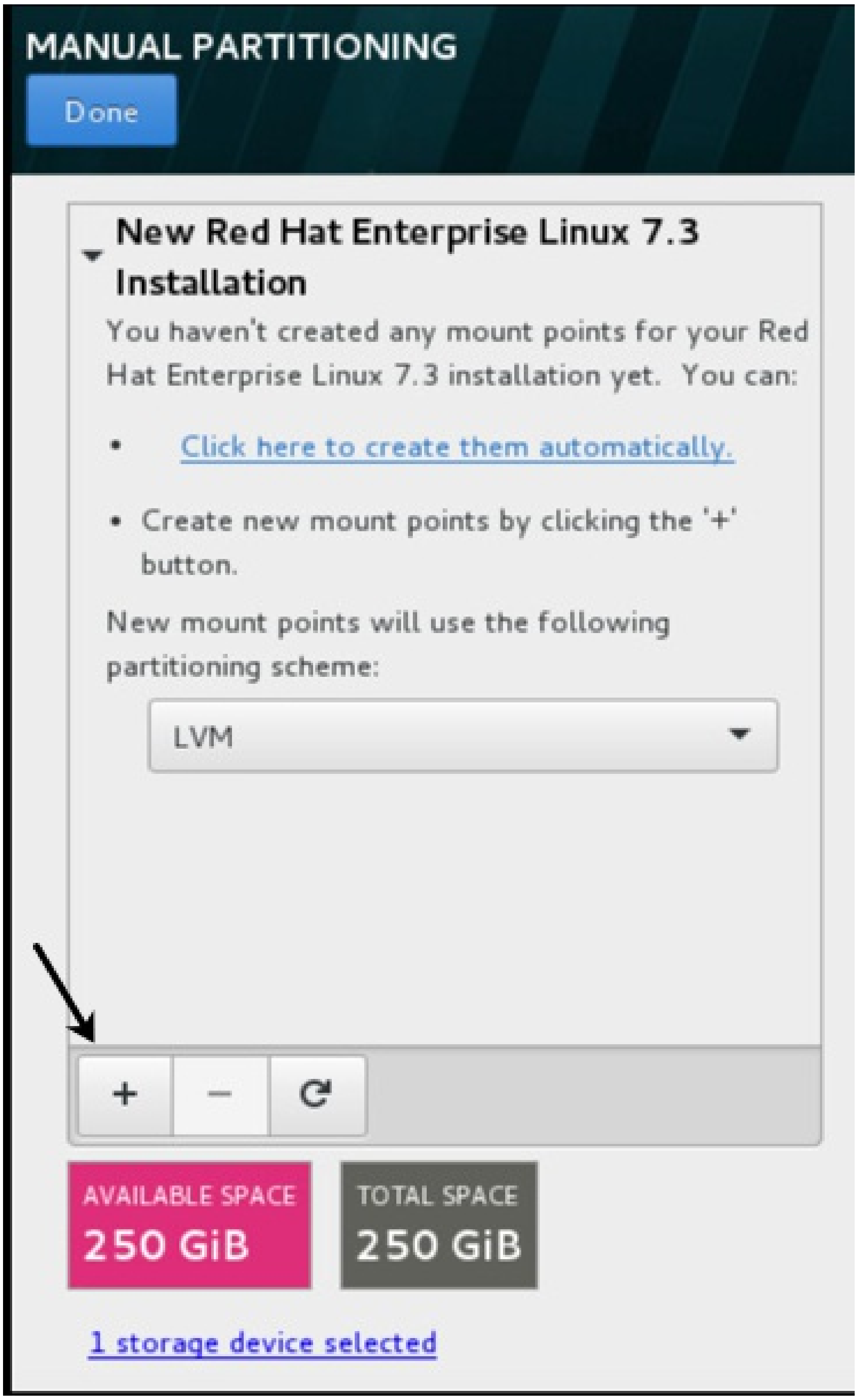
Encryption

☐ Encrypt my data. *You'll set a passphrase next.*

1 disk selected; 250 GiB capacity; 250 GiB free

- Once you have indicated that you want to customize the disk partitions, click on the blue Done button in the upper left corner.

- The next screen will allow you define multiple mount points and file system size for each mount point. (See figure below.)


MANUAL PARTITIONING

Done

New Red Hat Enterprise Linux 7.3 Installation

You haven't created any mount points for your Red Hat Enterprise Linux 7.3 installation yet. You can:

- Click here to create them automatically.
- Create new mount points by clicking the '+' button.

New mount points will use the following partitioning scheme:

LVM

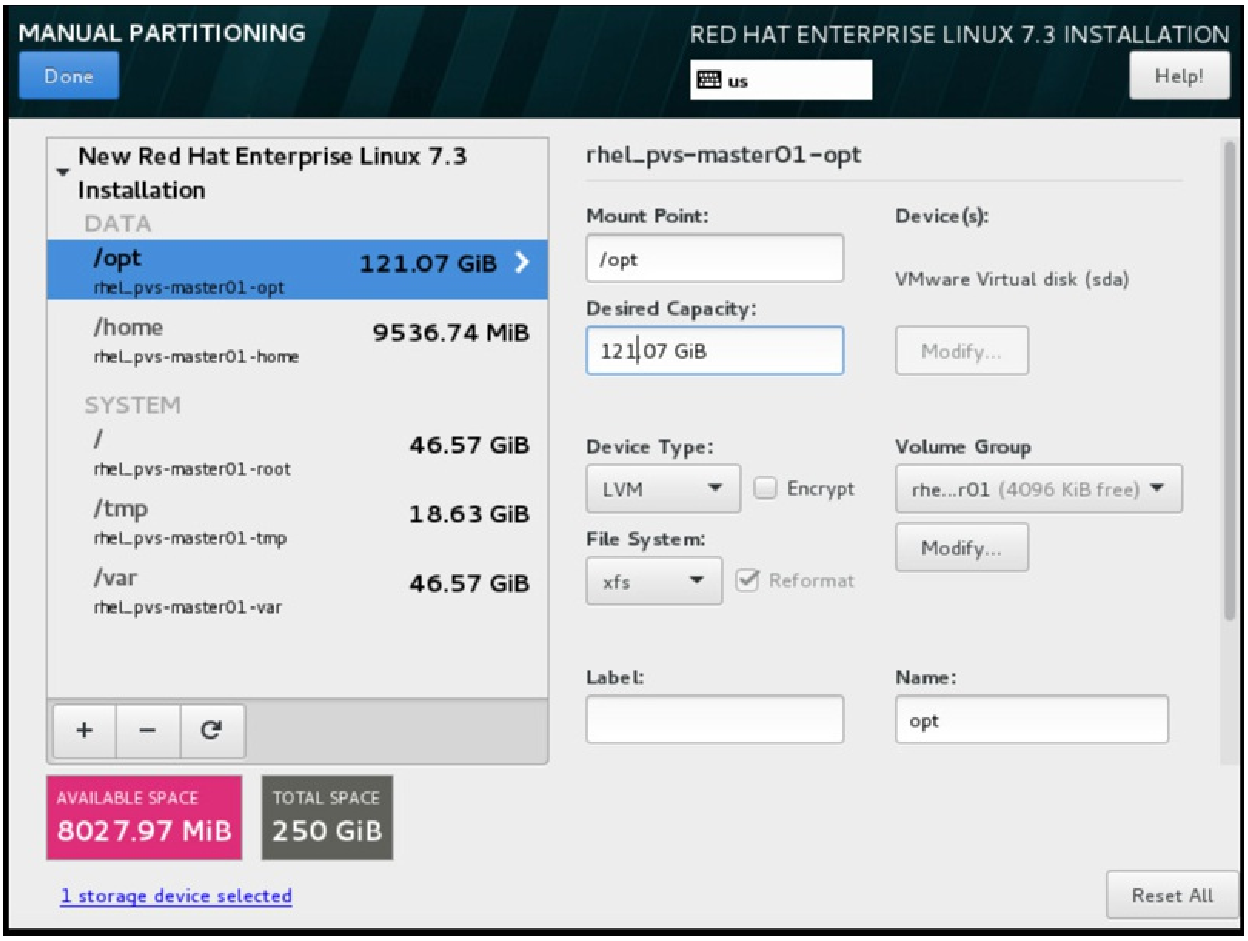
NOTE: The partitions are configured to use LVM except for the boot and swap partitions. The boot partition needs to be a "standard disk" partition. The recommended boot partition size is relatively small: 250 MB. It only needs to hold the boot loader, the kernel and some other low level system files.

TBD: The swap space is also a standard disk partition.

The following table is a summary of the sample disk partitions.

File System Name	Mount Point	Size (GB)
system (aka root)	/	40
boot	/boot	256 MB
swap		8
var	/var	60
tmp	/tmp	20
home	/home	20
opt	/opt	120

The figure below is a screen shot after the disk has been fully partitioned. (The partition sizes in the screen shot are slightly different from those in the table above.)


MANUAL PARTITIONING

RED HAT ENTERPRISE LINUX 7.3 INSTALLATION

New Red Hat Enterprise Linux 7.3 Installation

DATA

/opt rhel_pvs-master01-opt 121.07 GiB

/home rhel_pvs-master01-home 9536.74 MiB

SYSTEM

/ rhel_pvs-master01-root 46.57 GiB

/tmp rhel_pvs-master01-tmp 18.63 GiB

/var rhel_pvs-master01-var 46.57 GiB

AVAILABLE SPACE 8027.97 MiB

TOTAL SPACE 250 GiB

rhel_pvs-master01-opt

Mount Point: /opt

Device(s): VMware Virtual disk (sda)

Desired Capacity: 121.07 GiB

Device Type: LVM

Encrypt

File System: xfs

Reformat

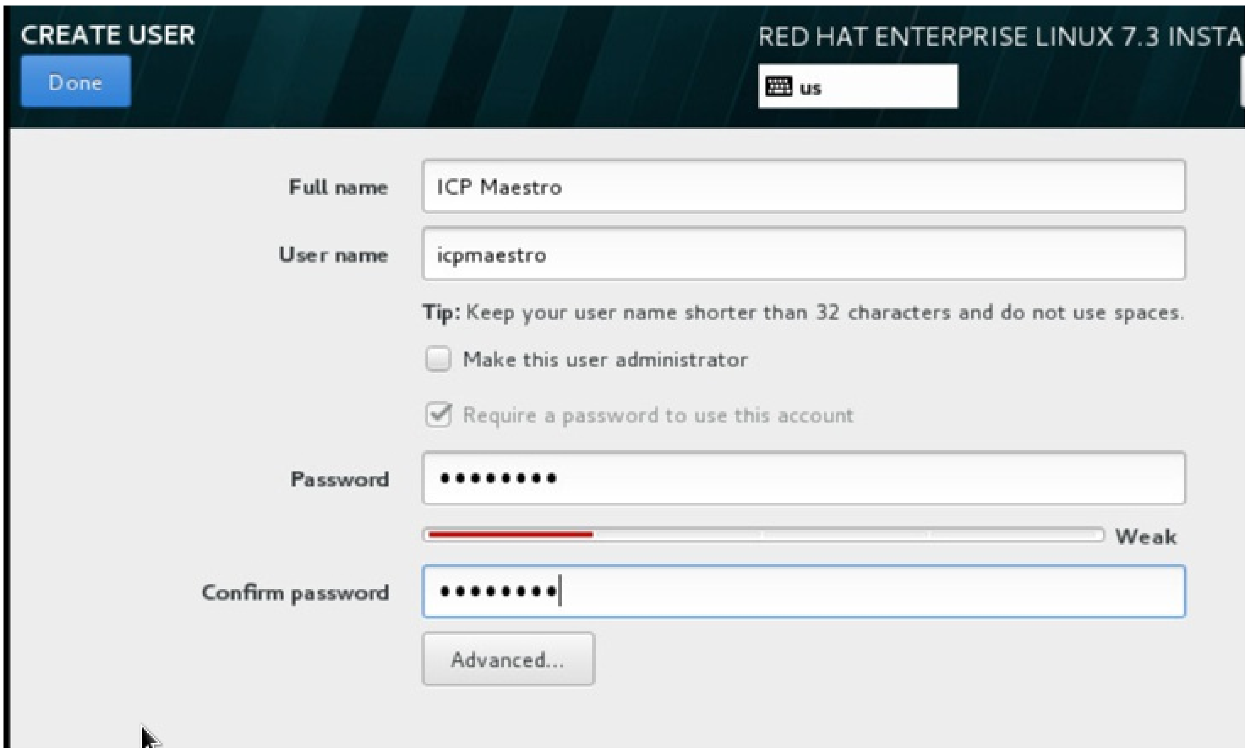
Volume Group: rhe...r01 (4096 KiB free)

Label:

Name: opt

- Once you finish defining the disk partitions, click on the Done button in the upper left corner of the screen. You will be returned to the Software Summary screen.

- At this point you can click on "Begin Installation" in the lower right corner of the Software Summary screen.
- In the next screen you need to provide the root password.
- Create a default user. In this sample, a user named "ICP Maestro" with user ID `icpmaestro` is created.



Full name: ICP Maestro

User name: icpmaestro

Tip: Keep your user name shorter than 32 characters and do not use spaces.

☐ Make this user administrator

✓ Require a password to use this account

Password: ••••••••• Weak

Confirm password: •••••••••

- Once the installation has completed, a reboot button will appear in the lower right corner of the final installation screen. The reboot completes the installation.
- Using the console, log in and get the IP address (`ip addr` or `ifconfig -a`) of the new VM and record it in your machine inventory.
- At this point you should be able to `ssh` to the machine either as root or as the default user you defined.

File system space work-arounds

With Linux there are a number of things you can do when you run low on file system space in a particular partition (file system).

With ICP installations the most common file system that fills up (possibly unexpectedly) is `/var`.

Sometimes file system space issues arise because a naive VM deployment has most of the disk allocated to some default that is inappropriate for an ICP runtime, e.g., a large amount of the disk allocated to `/home`.

Logical Volume Manager is your friend

NOTE: The VMs in a production deployment of ICP should have been created using the Logical Volume Manager for all file systems other than those that must use a physical partition, e.g., `/boot`.

If the file system that needs more space is defined using the Logical Volume Manager (LVM) it is relatively straight-forward to add more physical disk to your VM and then use that to expand the file systems that need more space. Have your system administrator assist you if you don't have the appropriate access to your hosting environment or the specific VM to carry out the necessary steps.

If you cat out `/etc/fstab`, you can easily tell which file systems are configured to use LVM:

```
> cat /etc/fstab
...
/dev/mapper/rhel_pvs--master01-root /                       xfs     defaults
UUID=25c62d51-b6a0-4de6-ba27-74eba4dbcec2 /boot             xfs     defaults
/dev/mapper/rhel_pvs--master01-home /home                   xfs     defaults
/dev/mapper/rhel_pvs--master01-opt /opt                     xfs     defaults
/dev/mapper/rhel_pvs--master01-tmp /tmp                     xfs     defaults
/dev/mapper/rhel_pvs--master01-var /var                     xfs     defaults
UUID=4c83db4c-bb2a-4867-8494-56b20cf8bc1f swap              swap    defaults

...
```

In the above listing, all file systems that have a line that starts with `/dev/mapper` are using LVM.

Those file systems with a line starting with `UUID=uniquifier_string` are a physical partition. In the above listing that would be `/boot` and `swap`, both of which are required to be physical partitions.

TODO: Add a description of the steps to do add disk and expand a file system.

Symlinks can be your friend

If one file system on a VM needs more space, e.g., `/var`, and another file system has a lot of free space, then one work-around is to use a symlink to allow directory trees to be moved to the file system where there is plenty of space. Keep in mind this is a bit of a hack and not generally recommended. But for some situations, e.g., non-production deployments, this is a reasonable work-around.

This section describes the steps to rearrange the file system space in `/var` which was running out of space during an upgrade of ICP to a newer version.

The `du -h` command is very useful in determining which directories are consuming space. The output of `du` is verbose so it is a good idea to tee it out to a file and then look at the results in the file.

```
du -h /var | tee -a du-var.out
```

On an ICP VM, the two big hitters in `/var` are going to be `/var/lib/docker` and `/var/lib/kubelet`. In this example, the `/var/lib/docker` directory is moved to `/opt/var/lib`. (Assume the `/opt` file system has a lot of available space.)

Since docker is using files and directories in `/var/lib/docker`, the docker process needs to be stopped before messing with its files.

- Stop docker (and check that it is stopped) (`systemctl stop docker` and `systemctl status docker`)
- Create a directory in `/opt`. Here a similar path was used to make its purpose clear.

```
> mkdir -p /opt/var/lib
```

- Tar up the `/var/lib/docker` directory tree into `/opt/var/lib/docker.tar`. In this case the tar ball will be rooted at `docker`.

```
> cd /var/lib
> tar cvf /opt/var/lib/docker.tar docker
```

- Extract the `docker.tar` archive in `/opt/var/lib`

```
> cd /opt/var/lib
> tar xvf docker.tar
```

- Go back to `/var/lib` and delete the `docker` directory tree

```
cd /var/lib
rm -rf docker
```

Now, at this point there may be 1 to several directories that you get a "device or resource busy" error. Usually an `umount` on those directories cleans that up and you can `rm -rf docker`.

You may run into a situation where the `umount` command does not unmount the offending directory, as it claims it is not mounted.

It may be in use by some process in which case `fuser -k` on that directory is intended to kill any process with a handle on anything in that directory tree. If you want ot be more careful about things, then `fuser -m` will list PIDS and a special access type letter for all processes accessing the directory tree. (See fuser man page for more details.) (The `fuser` command is the modern equivalent to `lsof`. Neither `fuser` nor `lsof` are typically installed on a base RHEL image. To get `fuser`, use `yum -y install psmisc`. To get `lsof`, use: `yum -y install lsof`.)

If all else fails a disable docker (`systemctl disable docker`) so that it does not start on boot-up, and reboot (`shutdown -r now`) the VM to clean things up. Then you can finally `rm -rf /var/lib/docker`. Be sure to enable docker (`systemctl enable docker`). (Do not start docker, yet.)

Once the original `/var/lib/docker` directory is deleted you can set up a symlink to the new location for the docker directory tree content.

- Create a symlink to `/opt/var/lib/docker` from `/var/lib/docker`.

```
> ln -s /opt/var/lib/docker /var/lib/docker
```

- Check the symlink.

```
ls -l /var/lib
```

You should see in `/var/lib` a link to docker: `docker -> /opt/var/lib/docker`.

- Start docker, `systemctl start docker` and check that it started, `systemctl status docker`.

- Delete the `docker.tar` file in `/opt/var/lib`.

Now there should be sufficient space available to grow the docker lib directory.

Sample HA install step-by-step

- Create the VMs
    - Allocate the disk to the file systems
    - Most of the VMs are created by cloning the first one
- Configure network on each VM with static IP
- Set the hostname
- Configure DNS with cluster host names or create /etc/hosts on boot-master and copy to all nodes
- Configure passwordless SSH
- Install Ansible on boot-master
- Configure all nodes to allow Ansible user (icpmaestro) passwordless sudo
- Configure yum repos or RHS (preferred)
- Update to latest RHEL RPMs (7.4) Reboot all nodes to pick up kernel updates.
- Install NTP on all nodes
    - Start and enable ntpd service
- Set vm.max_map_count on all nodes
    - Set immediately and for reboot in `/etc/sysctl.conf`
    - Ansible lineinfile path= `/etc/sysctl.conf` line='vm.max_map_count=262144' insertafter=EOF state=present
- Install Docker on all nodes
    - Start and enable Docker service
    - Ansible lineinfile path= `/lib/systemd/system/docker.service` line='MountFlags=False' insertafter= `StartLimitInterval=*` state=present
    - Restart docker on all nodes
- Install ICP
    - Load docker images from ICP install tar ball on the boot-master node.
    - Get the initial ICP install artifacts
    - Configure ICP hosts file; copy root ssh id_rsa to ssh_key; edit config.yaml
    - Stop firewalld on all nodes

    - Move ICP install tar ball to images directory in /cluster
    - Kick off the install
- Install kubectl on all of the master nodes (at a minimum on the boot-master node)
    - `docker run --net=host -v /usr/local/bin:/data ibmcom/kubernetes:v1.9.1-ee cp /kubectl /data`