Disruptive Storage Workshop
Hands-On ZFS

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http://www.pinedalab.org/disruptive-storage-workshop/

JOHNS HOPKINS
BLOOMBERG SCHOOL
of PUBLIC HEALTH

Schedule

- Setting up our VM (15 minutes)
- Installing ZFS (15 minutes)
- ZFS Configuration and Administration (60 minutes)

Setting up our VMs

Prerequisites

- ssh client - ssh/Putty/Mobaxterm
- VirtualBox
- Centos VM from either Globus endpoint: jhpce#dsw or http://www.pinedalab.org/img/Centos6.6-Base.ova

- 20GB of free disk space
- Fairly fast 64 bit CPU
- 4 GB of RAM

Setup VirtualBox and Import VM

- Create "Host Only Network" in Virtual Box
  - Navigate to “Virtual Box "-> “Preferences” -> “Network” -> “Host Only Network” tab
  - If there is no Adapter (“vboxnet0” on MacOS) create one by clicking on the green “+”
  - Double click on "vboxnet0" and make sure that the IP address is "192.168.56.1" and netmask is 255.255.255.0

- In VirtualBox, Go to “File” -> “Import Appliance”.
  - Navigate to location of "Centos6.6-Base.ova" file, and import with defaults
  - ** NOTE: Do not start the VM

Create VM clone for ZFS

- Right-click on “Centos 6.6 Base” VM and select “Clone”
- Name clone “ZFS1”
- Make sure you check “Reinitialize the MAC Address”

- Select “Full Clone”

- Once the ZFS1 VM is ready, start the VM.

ZFS1 setup

- Login on console: root/password
- cd /software
- Run “./demo-setup zfs1”
- Reboot

- Notes about console:
  - To escape, hit either Left-⌘ or Right-CTRL
  - Page Up - <Shift>-<fn>-<up-arrow>
  - Page Down - <Shift>-<fn>-<down-arrow>

Login via ssh

May find it easier to use a friendlier shell interface than the console. You can login to the VM by bringing up an ssh client (from a Terminal on Macs, or with Putty or MobaXterm on a PC), and then connecting to 192.168.56.11 and logging in as root:

$ ssh root@192.168.56.11

Installing ZFS

Install ZFS software

All commands that we will be doing for the lab (including the ones below) are in the file /software/STEPS.zfs

```
# yum localinstall --nogpgcheck \
    https://download.fedoraproject.org/pub/epel/6/x86_64/epel-release-6-8.noarch.rpm

# yum localinstall --nogpgcheck \
    http://archive.zfsonlinux.org/epel/zfs-release.el6.noarch.rpm

# yum install kernel-devel-2.6.32-504.el6.x86_64 kernel-headers-2.6.32-504.el6.x86_64
# yum install glibc-devel-2.12-1.149.el6.x86_64 glibc-headers-2.12-1.149.el6.x86_64

# yum install zfs-0.6.3
```

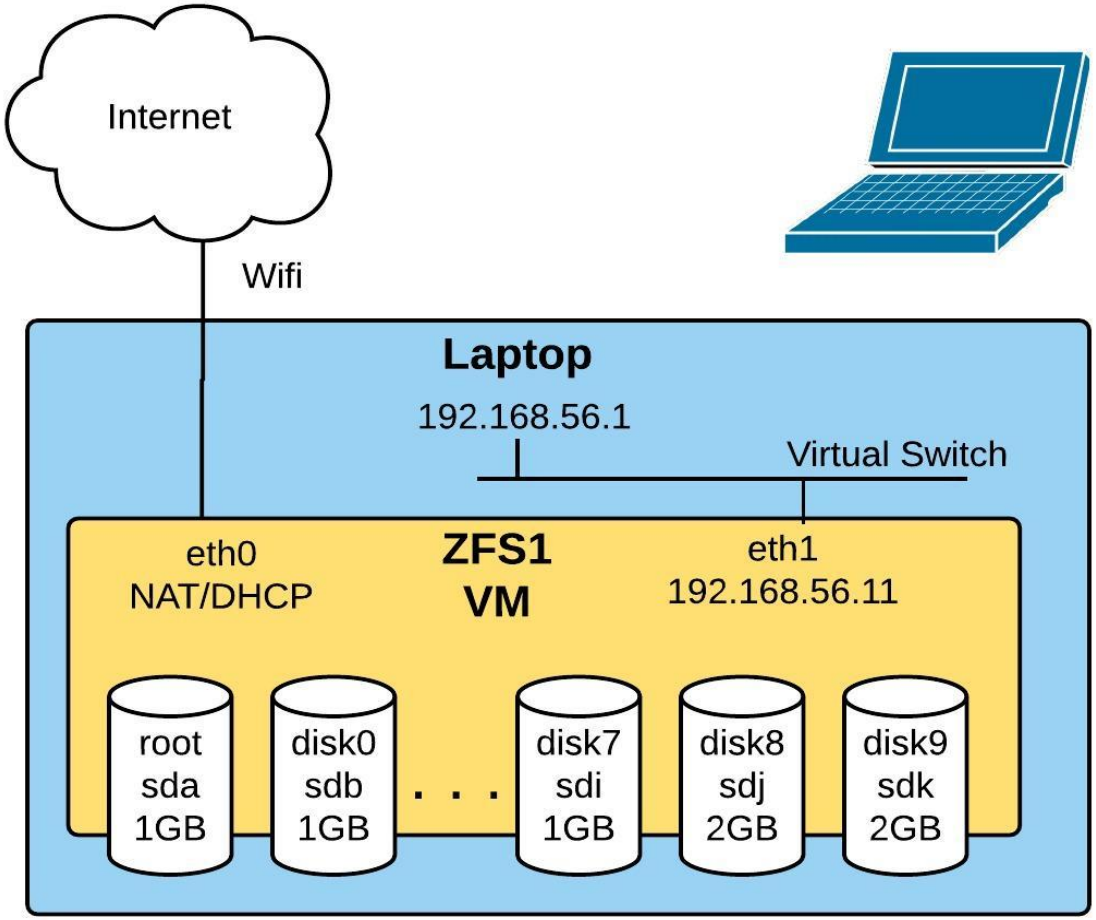
If you do not have network access, these RPMs are included in the VM

```
# cd /software/zfs/prereqs
# yum --disablerepo=\* install *
# cd /software/zfs
# yum --disablerepo=\* install *
```

DKMS - Dynamic Kernel Module Support - Kernel modules get compiled for each kernel version.

http://zfsonlinux.org/epel.html

Layout of our Virtualbox VM



- Added 8 x 1GB Virtual Drives and 2 x 2GB Virtual Drives (Dynamically Allocated)
- Added second Network Interface of type “Host Only”

Notes about VM

- Standard Centos Linux 6.6 image
- Enabled Centos 6.6 Vault access for yum.
- Created /software directory for lab scripts and staged packages
- chkconfig iptables off, selinux disabled
- Modified /etc/grub to show boot messages (removed “quiet” and “rhgb”
- set the root password set to “passwd”
- installed "parted", "rsync", and "man" packages via “yum install”
- Added /etc/hosts entries

Differences between VM and real world

- No card/driver issues to deal with
- No cabling
- No faulty hardware
- Much faster reboots
- Not really worried about I/O performance
- Provisioning work already done

- ** Please make sure you are not logged into VMs and production systems **

Last bits of setup

ZFS is now installed and running…but…

Create handy disk aliases with vdev_id. The “vdev_id” is a

udev helper (/lib/udev/rules.d/69-vdev.rules) that comes

bundled with zfs.

Last last bit of setup

Need to Label disks:

```
# for DISK in /dev/disk/by-vdev/disk*
    do
    parted $DISK mklabel gpt
done
```

ZFS Configuration and Administration

RAID Levels for pools

ZFS Raid Levels:

- striped (RAID 0) - this is the default if no pool type is given
- mirror (RAID 1)
- striped-mirrored (RAID10)
- raidz (RAID5 - uses XOR for parity)
- raidz2 (RAID6 - uses XOR for one parity and Reed-Solomon code for the other parity)
- raidz3

Our First ZPOOL - mirror

To create our first ZFS pool, and ZFS filesystem:

```
# zpool create pool1 mirror disk0 disk1

# zpool list
# zpool status
# zfs list
# df -h


# zfs create pool1/zfs1

# zpool list
# zpool status
# zfs list
# df –h

# cp -R /etc /pool1/zfs1

? Why do we create zfs filesystems
    zpools are permanent, where zfs filesystems are
flexible
```

Our Second ZPOOL - RAIDZ

To create our Second ZFS pool, and ZFS filesystem:

```
# zpool create pool2 raidz disk2 disk3 disk4 disk5
# zfs create pool2/alice
# zfs create pool2/bob
```

```
# zpool list
# zpool status
# zfs list
# df -h
```

To Note that "zpool list" on a "raidz" pool will show raw space without taking into account parity.

Destroying a ZPOOL/ZFS

As with unmounting a standard filesystem, a ZFS filesystem must not be in use for it to be deleted.

```
# zfs list
# df -h

# cd /pool2/alice
# zfs destroy pool2/alice
# cd /
# zfs destroy pool2/alice

# zfs list
# df -h


# zpool destroy pool2

# zpool list
# zpool status
# zfs list
# df -h
```

Growing a ZPOOL by adding stripes

You can add an additional similar VDEVs

```
# zpool add -n pool1 mirror disk2 disk3
# zpool add pool1 mirror disk2 disk3
# zpool status
# zpool list -v
# zfs list
# df -h
```

We've just created a RAID10! The same structure could have been done at the beginning with:

```
zpool create pool1 mirror disk0 disk1 mirror disk2 disk3
```

Additional VDEVs that get added to a zpool will be treated as additional stripes. New writes will favor VDEVs with lower usage, so this may affect performance.

Growing a zpool with bigger disks

Replacing 1GB disks with 2GB disks.

```
# zpool set autoexpand=on pool1
# zpool status; zpool list -v; df -h

# zpool replace pool1 disk2 disk8
# zpool status; zpool list -v; df -h

# zpool replace pool1 disk3 disk9
# zpool status; zpool list -v; df -h

# zpool replace pool1 disk8 disk2
cannot replace disk8 with disk2: device is
too small
```

http://blog.ociru.net/2013/09/25/let-your-zfs-extend

Adding a spare to a ZPOOL

Spares are used to replace a failed drive in a zpool

```
# zpool add pool1 spare disk4
# zpool status
# zpool list
# zfs list
```

NOTE - Spares do not automatically kick in in the event of a disk failure on ZoL.

Adding an SLOG device to a ZPOOL to be used as a ZIL

Separate Intent Logs (SLOGs) are used to speed up **writes** to the ZFS filesystem. They are not a write cache, but enable metadata to be written quickly so that response can be given. ZILs are never read from unless a recovery is needed. Typically these are very fast SSD disks.

```
# zpool add pool1 log disk5
# zpool status
# zpool list
# zfs list
```

Log devices should be mirrored.

```
# zpool remove pool1 disk5
# zpool add pool1 log mirror disk5 disk6
```

http://www.zfsbuild.com/2010/06/03/howto-zfs-add-log-drives-zil/
https://forums.freenas.org/index.php?threads/some-insights-into-slog-zil-with-zfs-on-freenas.13633/

Adding a cache device (L2ARC) to a ZPOOL

Cache devices are used to speed up **reads** to the ZFS filesystem. Typically these are very fast SSD disks.

```
# zpool add pool1 cache disk7
# zpool status
# zpool list
# zfs list
```

https://blogs.oracle.com/brendan/entry/test
http://queue.acm.org/detail.cfm?id=1809426

Removing devices from a ZPOOL

Only hot spares, cache (L2ARC), and log (zil) devices can be removed from a pool.

```
# zpool status
# zpool remove pool1 disk7
# zpool status
# zpool remove pool1 disk6
# man zpool
# zpool remove pool1 mirror-2
# zpool status
```

https://blogs.oracle.com/brendan/entry/test
http://queue.acm.org/detail.cfm?id=1809426

Scrubbing a ZPOOL

Each zpool should be scrubbed on a regular basis to identify potential disk errors.

```
# zpool status
# zpool scrub pool1
# zpool status
```

Resilvering

Scrubbing and resilvering are very similar operations. The difference is that resilvering only examines data that ZFS knows to be out of date (for example, when replacing an existing device), whereas scrubbing examines all data to discover silent errors due to hardware faults or disk failure.

Zpool import and export

Typically used when moving pools between dual-connected servers

```
# zpool export pool1
```

Note - just like unmount, this will not work if the pool or ZFS filesystem is in use

```
# zpool import
# zpool import pool1
```

To import a zpool that has become compromised

```
# zpool import -F pool1
```

To forcibly import a zpool that will not import

```
# zpool import -f pool1
```

Controlling what gets imported at boot

By default, when you reboot, any pools that are imported will get imported upon reboot. This is controlled by the `/etc/zfs/zpool.cache` file.

```
# strings /etc/zfs/zpool.cache | grep pool
# mv /etc/zfs/zpool.cache /etc/zfs/zpool.cache.old
# reboot
```

To rebuild the zpool.cache files, run

```
# zpool set cachefile=/etc/zfs/zpool.cache pool1
```

This can be run against any pool.

Setting attributes - ZPOOL

```
# zpool get all pool1
```

Notable attributes that can be set on the pool:

- `autoexpand`
- `ashift`
- `readonly`

Some settable attributes can be set in real time.

Some settable attributes can be set when the pool is imported.
One attribute can only be set at create time - `ashift`

```
# zpool set autoexpand=on pool1
# zpool import -o readonly=on pool1
# zpool create -o ashift=12 pool1
```

ZPOOL Setting - ashift

The `ashift` setting is used to set the sector size for I/O alignment. ashift=9 for older disks with 512b sectors and ashift=12 for newer drives with 4k sectors. Improves write performance, but causes more disk space overhead.

This can only be set at create time:

```
# zpool create -o ashift=12 pool1
```

http://louwrentius.com/zfs-performance-and-capacity-impact-of-ashift9-on-4k-sector-drives.html
http://lists.freebsd.org/pipermail/freebsd-fs/2013-May/017337.html

Setting attributes - ZFS

```
# zfs get all pool1/zfs1
```

Notable attributes that can be set on the pool:

- mountpoint
- quota
- reservation
- compression
- readonly
- sharenfs

Most attributes can be set in real time or at "zfs create" time

```
# zpool create pool2 raidz disk2 disk3 disk6 disk7
# zfs create pool2/chuck
# zfs create pool2/dave

# zfs set mountpoint=/chuck pool2/chuck
# df –h
# zfs create -o mountpoint=/eric pool2/eric
```

ZFS attributes - Quotas/Reservations

- Quotas are used on a ZFS filesystem to limit the size of a filesystem.

```
# zfs set quota=500M pool2/chuck
# df -h
# zfs set quota=none pool2/chuck
# df –h
```

- Reservations are used on a ZFS filesystem to reserve a portion of the ZPOOL for the ZFS filesystem.

```
# zfs set reservation=1G pool2/dave
# df –h
```

- Reservations and quotas can be combined.

```
# zfs set quota=1G pool2/dave
# df –h
```

Order of setting reservation and quota

Quota must always be larger than (or equal to) reservation

- To increase, set quota first, then reservation
- To decrease, set reservation, then quota

```
# zfs set quota=1G pool2/chuck
# zfs set reservation=1G pool2/chuck
# df -h
# zfs set reservation=800M pool2/chuck
# zfs set quota=800M pool2/chuck
```

ZFS attributes - Compression

Compression can be enabled on ZFS filesystems on the fly.

```
# df –h /chuck
# dd if=/dev/zero of=/chuck/zeros01 bs=1M count=100
# df –h /chuck     (shows 100 MBs used)

# zfs set compression=on pool2/chuck
# dd if=/dev/zero of=/chuck/zeros02 bs=1M count=100
# df –h /chuck     (shows ~101 MB used)
# ls -la /chuck
# du -sh /chuck/*
# du -sh --apparent-size /chuck/*

# dd if=/dev/urandom of=/chuck/random01 bs=1M count=100
# df –h            (shows ~201 MB used)

# zfs set compression=off pool2/chuck
# dd if=/dev/zero of=/chuck/zeros03 bs=1M count=100
# df –h            (shows ~301 MB used)
```

If compression is set, any data previously written will remain uncompressed - only new data will be compressed.

ZFS Snapshots

Creating Snapshots

```
# zfs snap pool2/chuck@snap1
# zfs list -t snapshot
# zfs list -t all

# dd if=/dev/zero of=/chuck/zeros04 bs=1M count=100
# ls -al /chuck
# ls -la /chuck/.zfs/
# ls -la /chuck/.zfs/snapshot
# zfs snap pool2/chuck@snap2
# ls -la /chuck/.zfs/snapshot
```

Hidden Snapshots?

```
# ls -al /chuck
# zfs set snapdir=visible pool2/chuck
# ls -al /chuck
```

Benefits of using ZFS Snapshots

Easy File Recovery

```
# cd /chuck
# ls -al
# df -h . ; zfs list -t snapshot
# rm random01
# ls -al
# df -h . ; zfs list -t snapshot
# cp .zfs/snapshot/snap2/random01 .
```

But snapshots take up space

```
# rm zeros03
# df -h . ; zfs list -t snapshot
# zfs destroy pool2/chuck@snap2
# df -h . ; zfs list -t snapshot
```

ZFS Snapshot Rollback

An entire ZFS filesystem can be resorted back to a snapshot view with the "zfs rollback" command.

```
# touch /chuck/file1
# touch /chuck/file2
# zfs snap pool2/chuck@snap3
# touch /chuck/file3
# rm /chuck/file1
# ls -al /chuck (shows file1 file is gone)
# zfs rollback pool2/chuck@snap3
# ls -al /chuck
```

… shows file1 is back, but file3 is gone because we rolled back the filesystem to what it looked like at when "snap3" was taken

ZFS Send/Receive

ZFS send and ZFS recv are used to send a copy of a ZFS snapshot from 1 pool to another

```
# zfs list -t all
# zfs send pool2/chuck@snap1 | zfs recv pool1/zfs1-backup
# zfs list -t all
# ls -al /pool1/zfs1-backup
```

ZFS Send & Receive (remote)

ZFS Send & Receive can also be used to send snapshots over the network to another ZFS server. We cannot do this now, as we only have 1 server, but will do it tomorrow

```
[root@zfs1 zfs]# zfs list -t all
[root@zfs1 zfs]# zfs send pool2/chuck@snap1 | ssh host2 zfs
recv pool2/zfs1-backup

[root@host2 zfs]# zfs list -t all
NAME                       USED  AVAIL  REFER  MOUNTPOINT
pool1                      100M  1.86G    31K  /pool1
pool1/zfs1                 100M  1.86G   100M  /pool1/zfs1
pool1/zfs1@snap1              0      -   100M  -
pool2                      100M  2.80G  41.9K  /pool2
pool2/zfs1-backup          100M  2.80G   100M  /pool2/zfs1-
backup
pool2/zfs1-backup@snap1       0      -   100M  -
[root@host2 zfs]# ls -al /pool2/zfs1-backup
total 102363
drwxr-xr-x 2 root root         3 Sep  8 16:41 .
drwxr-xr-x 3 root root         3 Sep  9 11:24 ..
-rw-r--r-- 1 root root 104857600 Sep  8 16:36 file2
```

ZFS Tuning (condensed to1 slide…)

General principle is that not much tuning is needed. ZFS experts have already done a lot of tuning.

Realtime changes can be made to files in `/sys/module/zfs/parameters`

```
# cat /sys/module/zfs/parameters/zfs_arc_max
67719876608
# echo 42949672960 > /sys/module/zfs/parameters/zfs_arc_max
```

Permanent changes can be set in `/etc/modprobe.d/zfs.conf`

https://wiki.freebsd.org/ZFSTuningGuide
http://www.solarisinternals.com/wiki/index.php/ZFS_Evil_Tuning_Guide
http://www.princeton.edu/~unix/Solaris/troubleshoot/zfs.html
http://docs.oracle.com/cd/E26502_01/html/E29022/chapterzfs-1.html#scrolltoc

Zpool iostat

The "zpool iostat" command lets you look at disks statistics for your zpool.

```
# zpool iostat
# zpool iostat -v
```

ZED

ZED is the ZFS Event Daemon, and can be used to provided notification on events that occur within ZFS

- Need to enable email in /etc/zfs/zed.d/zed.rc
- No service is provided by default, so need to run “zed” to start.
- Triggered from "zpool events"
- Can be configured to auto-engage Hot Spares

Troubleshooting ZFS

Failure Scenario 1 - Disk Failure

In our VM, no easy way to “yank a disk”.

```
# zpool status
# init 0
```

In VirtualBox, remove "Disk 1", then start up the VM. Log back into your VM.

```
# zpool replace pool1 disk0 disk4
```

This will cause the vdev to rebuild on the hot spare.

Edit `/etc/zfs/vdev_id.conf` and change "disk0" config to use the path to disk5.

Run "`udevadm trigger`"

```
# zpool online pool1 disk0
# zpool replace pool1 disk0
```

Failure Sceanio 2
Disk corruption - The importance of scrubs and checksums

```
# dd if=/dev/urandom of=/dev/disk/by-vdev/disk0 bs=1M count=10
# zpool status
# find /pool1 -type f -exec cat {} > /dev/null \;
(generate traffic to slow down scrub)
# zpool status

# dd if=/dev/urandom of=/pool1/zfs1/random4 bs=1M count=1000 &
# zpool scrub pool1
# zpool status
# zpool clear pool1
# zpool status
```

Failure Scenario 3
Oops - zpool destroyed

```
# zpool destroy pool2
(ooops)
# zpool import
(oh no!)
# zpool import -D
(yay)
# zpool import -D pool2
(almost there)
# zpool import -D -f pool2
# zpool status ; df -h
```

http://docs.oracle.com/cd/E19253-01/819-5461/6n7ht6r0o/index.html

Failure Sceanrio 4
Oops - zfs destroy

May be able to use `zdb`, `zpool history` and `zpool import -N -o readonly=on -f -R /pool -F -T <transaction_id> <pool>`

Could not get this to work on the VMs.

https://forums.freenas.org/index.php?threads/all-data-gone-accidential-zfs-destroy.18240/
http://lists.freebsd.org/pipermail/freebsd-hackers/2013-July/043125.html

Upgrading ZFS

Upgrading ZFS can be done with the following commands:

```
# yum update zfs
# reboot
# zpool upgrade <pool>
```

Backups should be done prior to performing an upgrade.

Thanks for attending! Questions?