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Install ZFS file system on Ubuntu 14.04

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Introduction to RAID, Concepts of RAID and RAID Levels

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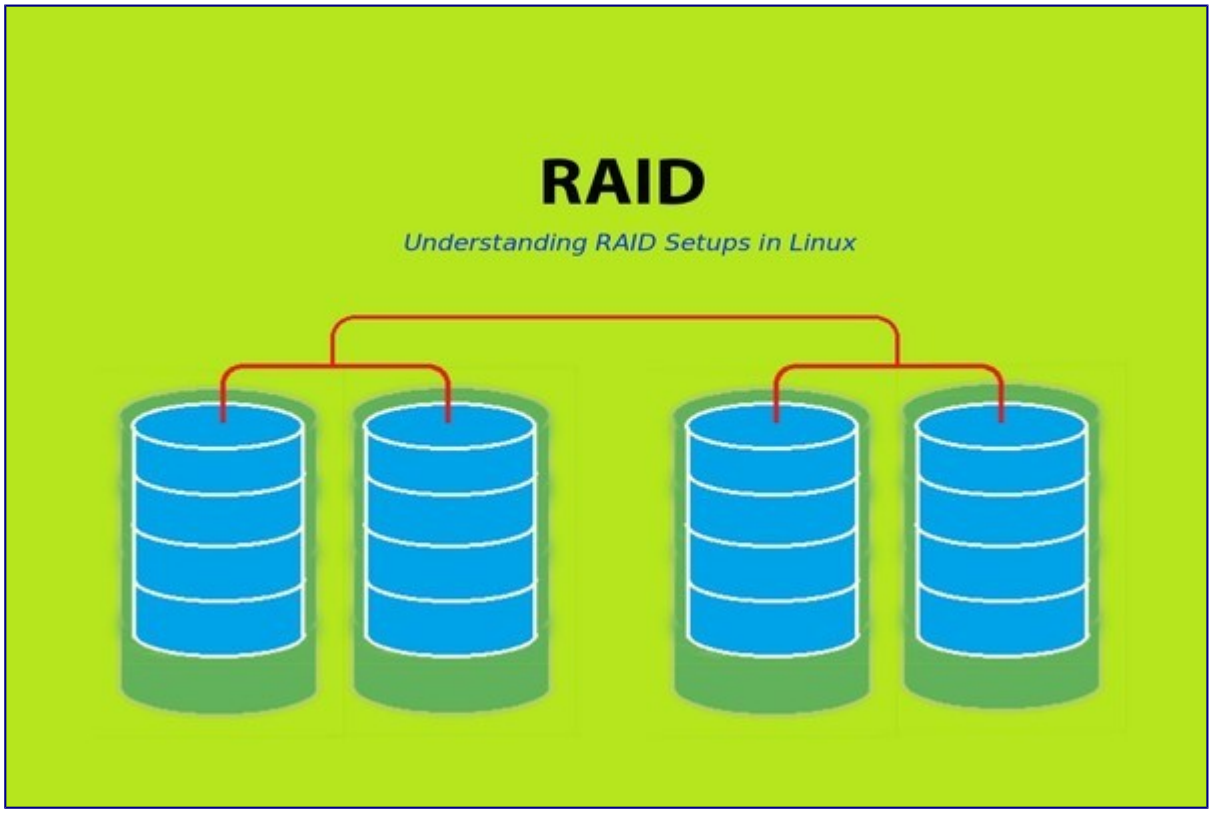
RAID is a Redundant Array of Inexpensive disks, but nowadays it is called Redundant Array of Independent drives. Earlier it is used to be very costly to buy even a smaller size of disk, but nowadays we can buy a large size of disk with the same amount like before. Raid is just a collection of disks in a pool to become a logical volume.



Software RAID have low performance, because of consuming resource from hosts. Raid software need to load for read data from software raid volumes. Before loading raid software, OS need to get boot to load the raid software. No need of Physical hardware in software raids. Zero cost investment.

Hardware RAID have high performance. They are dedicated RAID Controller which is Physically built using PCI express cards. It won't use the host resource. They have NVRAM for cache to read and write. Stores cache while rebuild even if there is power-failure, it will store the cache using battery power backups. Very costly investments needed for a large scale.

Featured Concepts of RAID

1. **Parity** method in raid regenerate the lost content from parity saved information's. RAID 5, RAID 6 Based on Parity.
2. **Stripe** is sharing data randomly to multiple disk. This won't have full data in a single disk. If we use 3 disks half of our data will be in each disks.
3. **Mirroring** is used in RAID 1 and RAID 10. Mirroring is making a copy of same data. In RAID 1 it will save the same content to the other disk too.
4. **Hot spare** is just a spare drive in our server which can automatically replace the failed drives. If any one of the drive failed in our array this hot spare drive will be used and rebuild automatically.
5. **Chunks** are just a size of data which can be minimum from 4KB and more. By defining chunk size we can increase the I/O performance.

RAID's are in various Levels. Here we will see only the RAID Levels which is used mostly in real environment.

1. **RAID0** = Striping
2. **RAID1** = Mirroring
3. **RAID5** = Single Disk Distributed Parity
4. **RAID6** = Double Disk Distributed Parity
5. **RAID10** = Combine of Mirror & Stripe. (Nested RAID)

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links ::
http://www.tecmint.com/understanding-raid-setup-in-linux/

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Install ZFS

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Before we can start using ZFS, we need to install it. Simply add the repository to apt-get with the following command:

 # sudo apt-add-repository --yes ppa:zfs-native/stable
 # sudo apt-get update
 # sudo apt-get install ubuntu-zfs
 # sudo reboot

Now, let's see if it has been correctly compiled and loaded by the kernel

 # sudo dmesg | grep ZFS
[5.979569] ZFS: Loaded module v0.6.3-5~trusty, ZFS pool version 5000, ZFS filesystem version 5

terminology

- **Datasets**

  Datasets are essentially groups of data or ZFS file systems that are stored on the raw data area that is a pool. Datasets are mounted just like any other FS (you can put them in your fstab) but by default they'll be mounted at pool/dataset off your root.

- **ZVOLs**

  ZVOLs are raw block devices crated over your pool. Essentially this is a new /dev/sdX that you can format however you like (ext4, xfs, even ZFS!) and it is backed by the integrity of the pool. A ZVOL is the most like hardware RAID you'll get out of ZFS.

- **L2ARC and SLOG**

  Something that is very powerful about ZFS is the ability to add fast drives (like SSDs or RAM drives) to pools of otherwise slow mechanic HDDs. These fast drives supplement your pool in hard times of read or synchronous write stress. The L2ARC is a read cache which is dynamically populated with your most likely to be needed read data (based on history) and the SLOG is a safe place that writes can go so an fsync can be returned before the data is dumped from RAM to HDD. I will likely have separate articles about these at a later date.

Some very useful ZFS concepts to understand

1. ZFS is a copy on write filesystem with snapshot capability. The reason this is important is because it gives you the ability to perform fully writable dataset/zvol clones in real-time with no performance hit and no space taken up (except what has actually changed). In my work this means if I need a clone of 20 virtual machines it takes less than 1 second, and it also means I can perform and keep 15 minute backups for 2 years with only 20% more space used.
2. ZFS supports real-time the compression modes of lzjb, gzip, zle & lz4. The ZFS manual currently recommends the use of lz4 for a balance between performance and compression.
3. ZFS supports de-duplication which means that if someone has 100 copies of the same movie we will only store that data once.
4. ZFS supports sending of entire datasets/zvols even pools to other ZFS system while online (even if the receiving pool is a different config)
5. All of these settings a hierarchical and tunable down to each dataset/zvol. You can have compression on one and not the other
6. ZFS can perform real-time scrubs
7. All changes can be made while the pool is online

We will use the zpool create command passing in the disks to use for the array as arguments. By specifying the argument -f it removes the need to create partitions on the disks prior to creating the array.

vdev	Desription	Pros	Cons
Single	Just a single disk, it fails you lose everything	Cheap Full use of disk space	Only one Disk speed It dies, you lose
Mirror	This is RAID-1 and can be as many disks as want 2/3/4/5 way mirros	Great data redundancy Fast read speed	Poor space efficiency Write speed of 1 disk
RaidZ1	Just like RAID 5, you're allowed to lose one disk without penalty	Great use of space Great read performance	Write penalty x4 Expensive Parity checks
RaidZ2	Just like RAID 6, you're allowed to lose two disks	Good use of space Great read performance	Write penalty x6 Slower than Raidz1
RaidZ3	Comparable to fictional RAID 7, you can lose three disks	Superior data protection Great read performance	Write penalty x8 Most expensive RAIDZ

```
# sudo zpool create pool raidz 01
invalid vdev specification: raidz requires at least 2 devices

# sudo zpool create pool raidz2 01
invalid vdev specification: raidz2 requires at least 3 devices
```

```
# sudo zpool create pool raidz3 01
invalid vdev specification: raidz3 requires at least 4 devices
```

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ZFS Virtual Devices (ZFS VDEVs)

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A VDEV is a meta-device that can represent one or more devices. ZFS supports 7 different types of VDEV:

- File - a pre-allocated file
- Physical Drive (HDD, SDD, PCIe NVME, etc)
- Mirror - a standard RAID1 mirror
- ZFS software raidz1, raidz2, raidz3 'distributed' parity based RAID
- Hot Spare - hot spare for ZFS software raid.
- Cache - a device for level 2 adaptive read cache (ZFS L2ARC)
- Log - ZFS Intent Log (ZFS ZIL)

VDEVS are dynamically striped by ZFS. A device can be added to a VDEV, but cannot be removed from it.

ZFS Pools

A zpool is a pool of storage made from a collection of VDEVS. One or more ZFS file systems can be created from a ZFS pool.

In the following example, a pool named "pool-test" is created from 3 physical drives:

```
# sudo zpool create pool-test /dev/sdb /dev/sdc /dev/sdd
```

Striping is performed dynamically, so this creates a zero redundancy RAID-0 pool.

Notice: If you are managing many devices, it can be easy to confuse them, so you should probably prefer /dev/disk/by-id/ names, which often use serial numbers of drives. The examples here should not suggest that 'sd_' names are preferred. They merely make examples herein easier to read.

One can see the status of the pool using the following command:

```
# sudo zpool status pool-test
```

...and destroy it using:

```
# sudo zpool destroy pool-test
```

A 2 x 2 mirrored zpool example

The following example, we create a zpool containing a VDEV of 2 drives in a mirror:

```
# sudo zpool create mypool mirror /dev/sdc /dev/sdd
```

next, we add another VDEV of 2 drives in a mirror to the pool:

```
# sudo zpool add mypool mirror /dev/sde /dev/sdf -f

# sudo zpool status

  pool: mypool
 state: ONLINE
  scan: none requested
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            sdc     ONLINE       0     0     0
            sdd     ONLINE       0     0     0
          mirror-1  ONLINE       0     0     0
            sde     ONLINE       0     0     0
            sdf     ONLINE       0     0     0
```

In this example:

- /dev/sdc, /dev/sdd, /dev/sde, /dev/sdf are the physical devices
- mirror-0, mirror-1 are the VDEVs
- mypool is the pool

There are plenty of other ways to arrange VDEVs to create a zpool.

A single file based zpool example

In the following example, we use a single 2GB file as a VDEV and make a zpool from just this one VDEV:

```
# dd if=/dev/zero of=example.img bs=1M count=2048
# sudo zpool create pool-test /home/user/example.img
# sudo zpool status

 pool: pool-test
 state: ONLINE
  scan: none requested
config:

        NAME                      STATE     READ WRITE CKSUM
        pool-test                 ONLINE       0     0     0
          /home/user/example.img  ONLINE       0     0     0
```

In this example:

- /home/user/example.img is a file based VDEV
- pool-test is the pool

RAID

ZFS offers different RAID options:

Striped VDEVS

This is equivalent to RAID0. This has no parity and no mirroring to rebuild the data. This is not recommended because of the risk of losing data if a drive fails. Example, creating a striped pool using 4 VDEVs:

```
# sudo zpool create example /dev/sdb /dev/sdc /dev/sdd /dev/sde
```

Mirrored VDEVs

Much like RAID1, one can use 2 or more VDEVs. For N VDEVs, one will have to have N-1 fail before data is lost. Example, creating mirrored pool with 2 VDEVs

```
# sudo zpool create example mirror /dev/sdb /dev/sdc
```

Striped Mirrored VDEVs

Much like RAID10, great for small random read I/O. Create mirrored pairs and then stripe data over the mirrors. Example, creating striped 2 x 2 mirrored pool:

```
# sudo zpool create example mirror /dev/sdb /dev/sdc mirror /dev/sdd /dev/sde
```

or:

```
# sudo zpool create example mirror /dev/sdb /dev/sdc
# sudo zpool add example mirror /dev/sdd /dev/sde
```

RAIDZ

Like RAID5, this uses a variable width strip for parity. Allows one to get the most capacity out of a bunch of disks with parity checking with a sacrifice to some performance. Allows a single disk failure without losing data. Example, creating a 4 VDEV RAIDZ:

```
# sudo zpool create example raidz /dev/sdb /dev/sdc /dev/sdd /dev/sde
```

RAIDZ2

Like RAID6, with double the parity for 2 disk failures with performance similar to RAIDZ. Example, create a 2 parity 5 VDEV pool:

```
# sudo zpool create example raidz2 /dev/sdb /dev/sdc /dev/sdd /dev/sde /dev/sdf
```

RAIDZ3

3 parity bits, allowing for 3 disk failures before losing data with performance like RAIDZ2 and RAIDZ. Example, create a 3 parity 6 VDEV pool:

```
# sudo zpool create example raidz3 /dev/sdb /dev/sdc /dev/sdd /dev/sde
/dev/sdf /dev/sdg
```

Nested RAIDZ

Like RAID50, RAID60, striped RAIDZ volumes. This is better performing than RAIDZ but at the cost of reducing capacity. Example, 2 x RAIDZ:

```
# sudo zpool create example raidz /dev/sdb /dev/sdc /dev/sdd /dev/sde
# sudo zpool add example raidz /dev/sdf /dev/sdg /dev/sdh /dev/sdi
```

ZFS Intent Logs

ZIL (ZFS Intent Log) drives can be added to a ZFS pool to speed up the write capabilities of any level of ZFS RAID. One normally would use a fast SSD for the ZIL. Conceptually, ZIL is a logging mechanism where data and metadata to be the written is stored, then later flushed as a transactional write. In reality, the ZIL is more complex than this and described in detail here. One or more drives can be used for the ZIL.

For example, to add a SSDs to the pool 'mypool', use:

```
# sudo zpool add mypool log /dev/sdg -f
```

ZFS Cache Drives

Cache devices provide an additional layer of caching between main memory and disk. They are especially useful to improve random-read performance of mainly static data.

Fox example, to add a cache drive /dev/sdh to the pool 'mypool', use:

```
# sudo zpool add mypool cache /dev/sdh -f
```

ZFS file systems

ZFS allows one to create a maximum of 2^64 file systems per pool. In the following example, we create two file systems in the pool 'mypool':

```
# sudo zfs create mypool/tmp
# sudo zfs create mypool/projects
```

and to destroy a file system, use:

```
# sudo zfs destroy mypool/tmp
```

Each ZFS file systems can have properties set, for example, setting a maximum quota of 10 gigabytes:

```
# sudo zfs set quota=10G mypool/projects
```

or adding using compression:

```
# sudo zfs set compression=on mypool/projects
```

ZFS Snapshots

A ZFS snapshot is a read-only copy of ZFS file system or volume. It can be used to save the state of a ZFS file system at a point of time, and one can roll back to this state at a later date. One can even extract files from a snapshot and not need to perform a complete roll back.

In the following example, we snapshot the mypool/projects file system:

```
# sudo zfs snapshot -r mypool/projects@snap1
```

..and we can see the collection of snapshots using:

```
# sudo zfs list -t snapshot
NAME                      USED  AVAIL  REFER  MOUNTPOINT
mypool/projects@snap1    8.80G      -  8.80G  -
```

Now lets 'accidentally' destroy all the files and then roll back:

```
# sudo rm -rf /mypool/projects
# sudo zfs rollback mypool/projects@snap1
```

One can remove a snapshot using the following:

```
# sudo zfs destroy mypool/projects@snap1
```

ZFS Clones

A ZFS clone is a writeable copy of a file system with the initial content of the clone being identical to the original file system. A ZFS clone can only be created from a ZFS snapshot and the snapshot cannot be destroyed until the clones created from it are also destroyed.

For example, to clone mypool/projects, first make a snapshot and then clone:

```
# sudo zfs snapshot -r mypool/projects@snap1
# sudo zfs clone mypool/projects@snap1 mypool/projects-clone
```

ZFS Send and Receive

ZFS send sends a snapshot of a filesystem that can be streamed to a file or to another machine. ZFS receive takes this stream and will write out the copy of the snapshot back as a ZFS filesystem. This is great for backups or sending copies over the network (e.g. using ssh) to copy a file system.

For example, make a snapshot and save it to a file:

```
# sudo zfs snapshot -r mypool/projects@snap2
# sudo zfs send mypool/projects@snap2 > ~/projects-snap.zfs
```

..and receive it back:

```
# sudo zfs receive -F mypool/projects-copy < ~/projects-snap.zfs
```

ZFS Ditto Blocks

Ditto blocks create more redundant copies of data to copy, just for more added redundancy. With a storage pool of just one device, ditto blocks are spread across the device, trying to place the blocks at least 1/8 of the disk apart. With multiple devices in a pool, ZFS tries to spread ditto blocks across separate VDEVs. 1 to 3 copies can be can be set. For example, setting 3 copies on mypool/projects:

```
# sudo zfs set copies=3 mypool/projects
```

ZFS Deduplication

ZFS dedup will discard blocks that are identical to existing blocks and will instead use a reference to the existing block. This saves space on the device but comes at a large cost to memory. The dedup in-memory table uses ~320 bytes per block. The greater the table is in size, the slower write performance becomes.

For example, enable dedup on mypool/projects, use:

```
# sudo zfs set dedup=on mypool/projects
```

For more pros/cons of deduping, refer to http://constantin.glez.de/blog/2011/07/zfs-dedupe-or-not-dedupe. Deduplication is almost never worth the performance penalty.

ZFS Pool Scrubbing

To initiate an explicit data integrity check on a pool one uses the zfs scrub command. For example, to scrub pool 'mypool':

```
# sudo zpool scrub mypool
```

one can check the status of the scrub using zpool status, for example:

```
# sudo zpool status -v mypool
```

Data recovery, a simple example

Let's assume we have a 2 x 2 mirror'd zpool:

```
# sudo zpool create mypool mirror /dev/sdc /dev/sdd mirror /dev/sde /dev/sdf -f
# sudo zpool status

  pool: mypool
 state: ONLINE
  scan: none requested
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            sdc     ONLINE       0     0     0
            sdd     ONLINE       0     0     0
          mirror-1  ONLINE       0     0     0
            sde     ONLINE       0     0     0
            sdf     ONLINE       0     0     0
```

Now populate it with some data and check sum the data:

```
# dd if=/dev/urandom of=/mypool/random.dat bs=1M count=4096
# md5sum /mypool/random.dat
f0ca5a6e2718b8c98c2e0fdabd83d943  /mypool/random.dat
```

Now we simulate catastrophic data loss by overwriting one of the VDEV devices with zeros:

```
# sudo dd if=/dev/zero of=/dev/sde bs=1M count=8192
```

And now initiate a scrub:

```
# sudo zpool scrub mypool
```

And check the status:

```
# sudo zpool status

 pool: mypool
 state: ONLINE
status: One or more devices has experienced an unrecoverable error.  An
        attempt was made to correct the error.  Applications are unaffected.
action: Determine if the device needs to be replaced, and clear the errors
        using 'zpool clear' or replace the device with 'zpool replace'.
   see: http://zfsonlinux.org/msg/ZFS-8000-9P
  scan: scrub in progress since Tue May 12 17:34:53 2015
    244M scanned out of 1.91G at 61.0M/s, 0h0m to go
    115M repaired, 12.46% done
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            sdc     ONLINE       0     0     0
            sdd     ONLINE       0     0     0
          mirror-1  ONLINE       0     0     0
            sde     ONLINE       0     0   948  (repairing)
            sdf     ONLINE       0     0     0
```

...now let us remove the drive from the pool:

```
# sudo zpool detach mypool /dev/sde
```

..hot swap it out and add a new one back:

```
# sudo zpool attach mypool /dev/sdf /dev/sde  -f
```

..and initiate a scrub to repair the 2 x 2 mirror:

```
# sudo zpool scrub mypool
```

ZFS compression

As mentioned earlier, one can compress data automatically with ZFS. With the speed of modern CPUs this is a useful option as reduced data size means less data to physically read and write and hence faster I/O. ZFS offers a comprehensive range of compression methods. The default is lz4 (a high performance replacement of lzjb) that offers faster compression/decompression to lzjb

and slightly higher compression too. One can change the compression level, e.g.

```
# sudo zfs set compression=gzip-9 mypool
```

or even the compression type:

```
# sudo zfs set compression=lz4 mypool
```

and check on the compression level using:

```
# sudo zfs get compressratio
```

lz4 is significantly faster than the other options while still performing well; lz4 is the safest choice.

Delete a dataset

```
# sudo zfs destroy datastore1/dataset1
```

Delete a pool

```
# sudo zpool destroy datastore1
```

Delete cache

```
# sudo zpool remove mypool cache /dev/sdh -fZFS Cache Drives
```

Delete ZIL

```
# sudo zpool remove mypool log /dev/sdg -f
```

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links ::

basics of RAID >>
http://www.tecmint.com/understanding-raid-setup-in-linux/

installation >>
http://blog.boyeau.com/quick-install-install-zfs-file-system-on-ubuntu-14-04/

installation and basic >>
http://kbdone.com/zfs-basics/

installation and shareing (samba) >>
http://serverascode.com/2014/07/01/zfs-ubuntu-trusty.html

working and config >>
https://wiki.ubuntu.com/Kernel/Reference/ZFS

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