ZFS
The Last Word in Filesystem

frank

What is RAID?

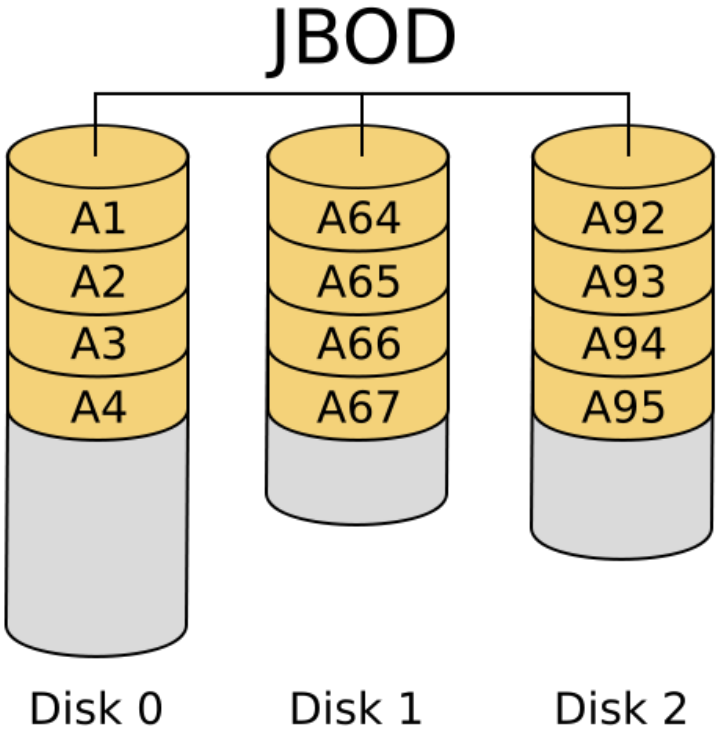
RAID

Redundant **A**rray of **I**ndepedent **D**isks
A group of drives glue into one

Common RAID types

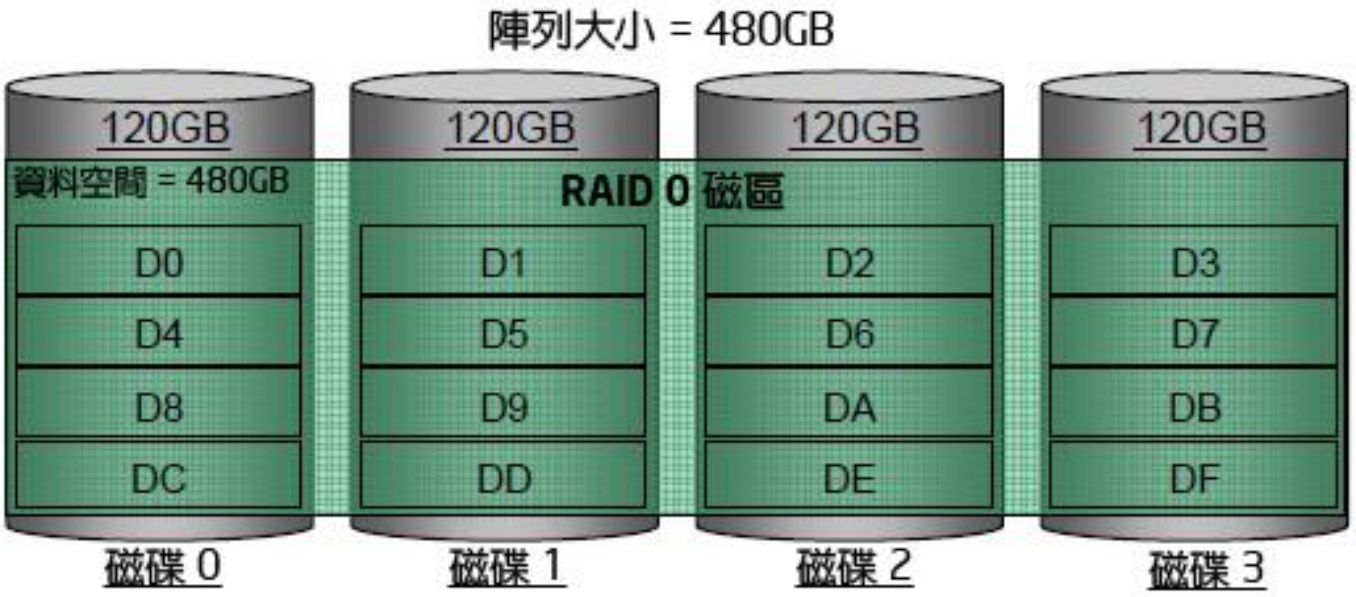
- **JBOD**
- **RAID 0**
- **RAID 1**
- **RAID 5**
- **RAID 6**
- **RAID 10?**
- **RAID 50?**
- **RAID 60?**

JBOD (Just a Bunch Of Disks)



http://www.mydiskmanager.com/wp-content/uploads/2013/10/JBOD.png

RAID 0 (Stripe)



http://www.intel.com/support/tw/chipsets/imsm/sb/cs-009337.htm

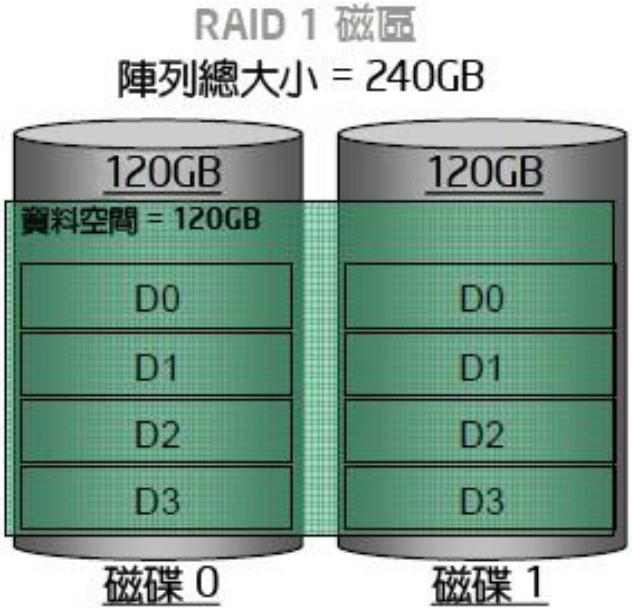
RAID 0 (Stripe)

Striping data onto multiple devices
2X Write/Read Speed

Data corrupt if ANY of the device fail.

http://www.intel.com/support/tw/chipsets/imsm/sb/cs-009337.htm

RAID 1 (Mirror)



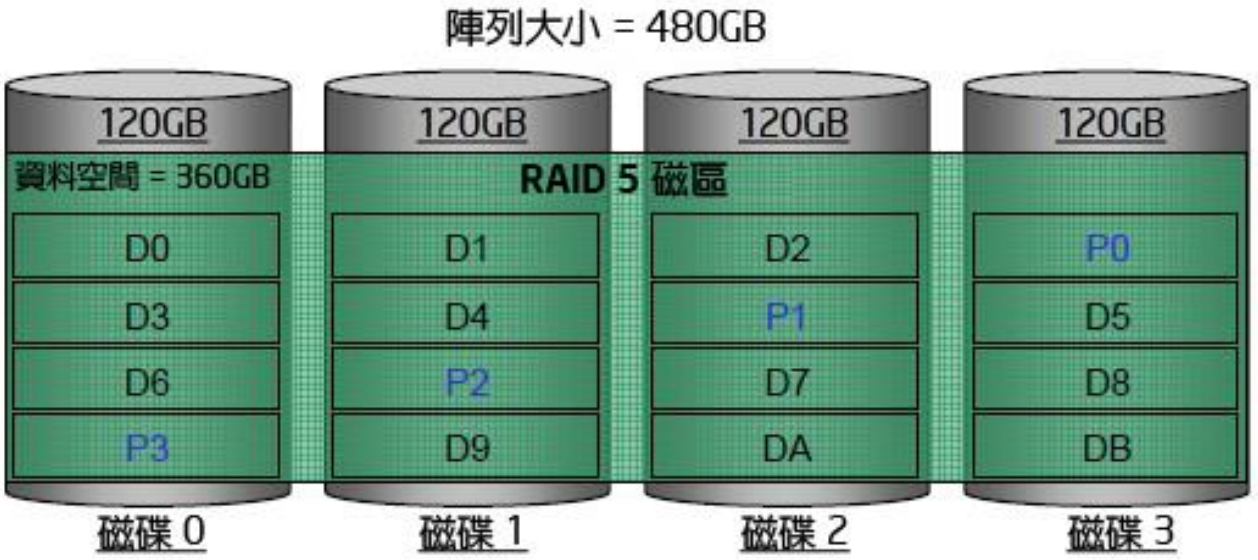
http://www.intel.com/support/tw/chipsets/imsm/sb/cs-009337.htm

RAID 1 (Mirror)

Devices contain identical data
100% redundancy
Fast read

http://www.intel.com/support/tw/chipsets/imsm/sb/cs-009337.htm

RAID 5



http://www.intel.com/support/tw/chipsets/imsm/sb/cs-009337.htm

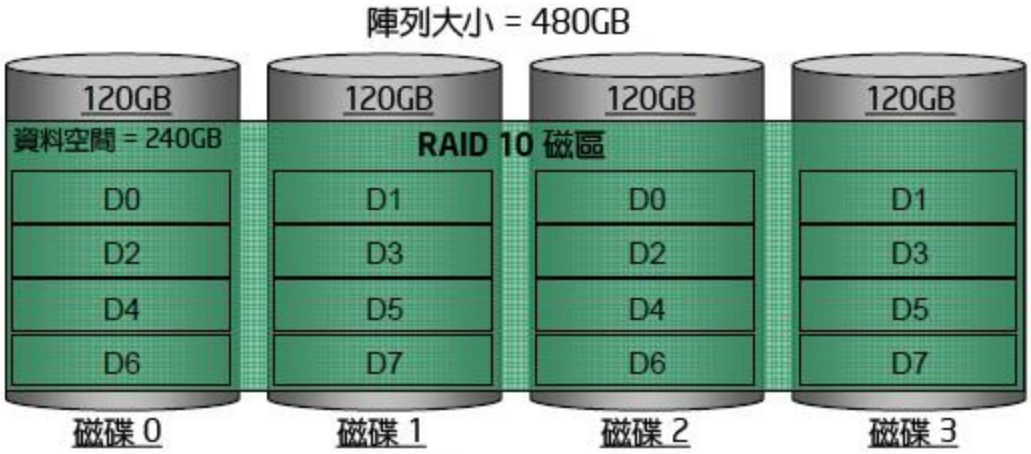
RAID 5

Slower the raid 0 / raid 1
Higher cpu usage

http://www.intel.com/support/tw/chipsets/imsm/sb/cs-009337.htm

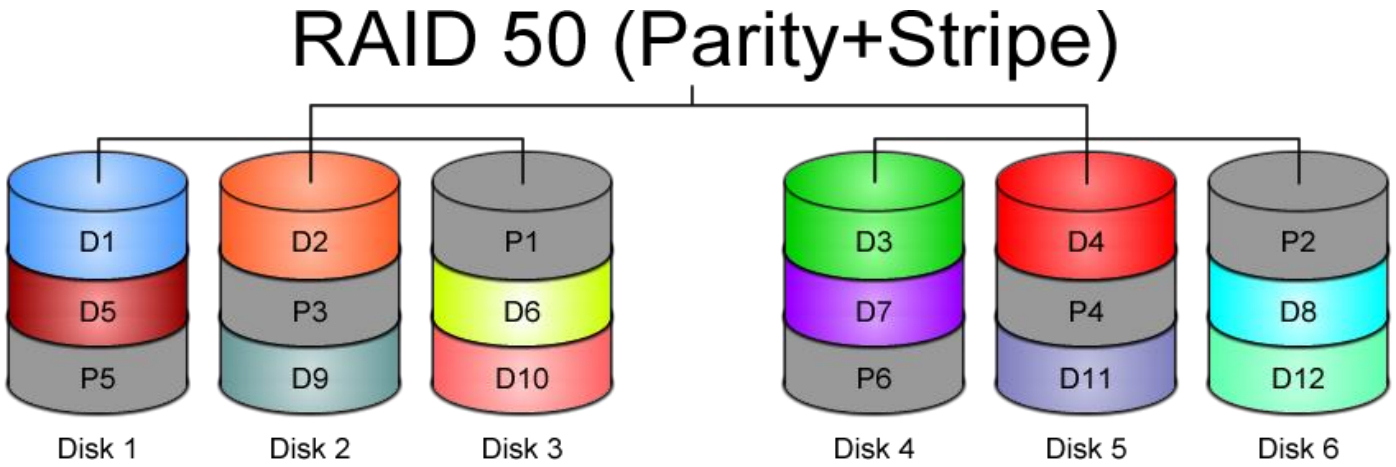
RAID 10?

RAID 1+0



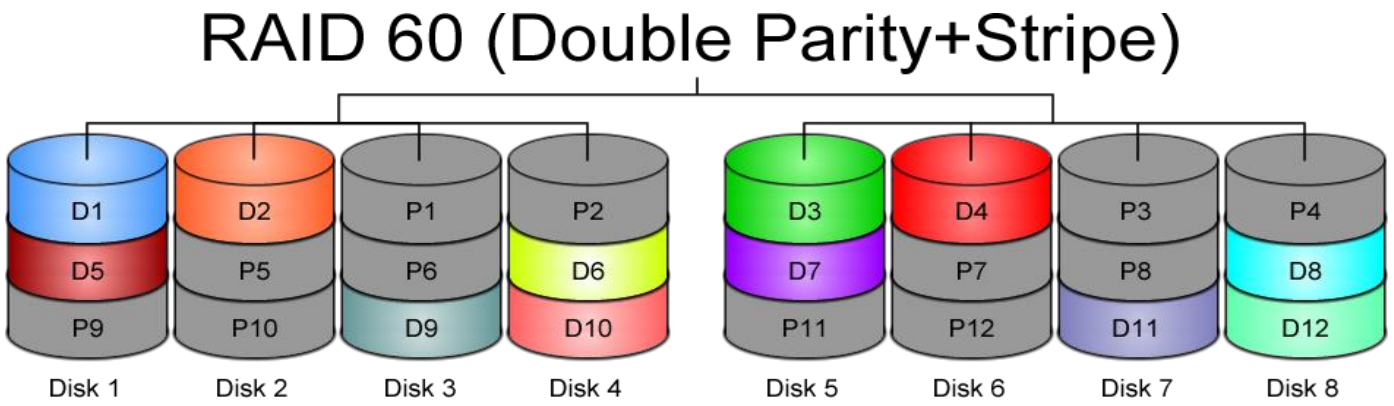
http://www.intel.com/support/tw/chipsets/imsm/sb/cs-009337.htm

RAID 50?



https://www.icc-usa.com/wp-content/themes/icc_solutions/images/raid-calculator/raid-50.png

RAID 60?



https://www.icc-usa.com/wp-content/themes/icc_solutions/images/raid-calculator/raid-60.png

Here comes ZFS

Why ZFS?

- Easy adminstration
- Highly scalable (128 bit)
- Transactional Copy-on-Write
- Fully checksummed
- Revolutionary and modern
- SSD and Memory friendly

ZFS Pools

ZFS is not just filesystem
ZFS = filesystem + volumn manager

- ❑ Work out of the box
- ❑ Zuper zimple to create
- ❑ Controlled with single command
  - ***zpool***

ZFS Pools Components

Pool is create from *vdevs* (Virtual Devices)
What is vdevs?
disk: A real disk (sda)
file: A file (caveat! https://bugs.freebsd.org/bugzilla/show_bug.cgi?id=195061)
mirror: Two or more disks mirrored together
raidz1/2: Three or more disks in RAID5/6*
spare: A spare drive
log: A write log device (ZIL SLOG; typically SSD)
cache: A read cache device (L2ARC; typically SSD)

RAID in ZFS

Dynamic Stripe: Intelligent RAID0
Mirror: RAID 1
Raidz1: Improved from RAID5 (parity)
Raidz2: Improved from RAID6 (double parity)
Raidz3: triple parity
Combined as dynamic stripe

Create a simple zpool

zpool create mypool /dev/sda /dev/sdb

Dynamic Stripe (RAID 0)

|- /dev/sda

|- /dev/sdb

```
zpool create mypool
        mirror /dev/sda /dev/sdb
        mirror /dev/sdc /dev/sdd
```

What is this?

WT* is this

```
zpool create mypool
        mirror /dev/sda /dev/sdb
          mirror /dev/sdc /dev/sdd
                raidz /dev/sde /dev/sdf /dev/sdg
                      log mirror /dev/sdh /dev/sdi
                        cache /dev/sdj /dev/sdk
                           spare /dev/sdl /dev/sdm
```

Zpool command

zpool list
list all the zpool
zpool status [pool name]
show status of zpool
zpool export/import [pool name]
export or import given pool
zpool set/get <properties/all>
set or show zpool properties
zpool online/offline <pool name> <vdev>
set an device in zpool to online/offline state
zpool attach/detach <pool name> <device> <new device>
attach a new device to an zpool/detach a device from zpool
zpool replace <pool name> <old device> <new device>
replace old device with new device

zpool scrub
try to discover silent error or hardware failure
zpool history [pool name]
show all the history of zpool
zpool add <pool name> <vdev>
add additional capacity into pool
zpool create/destroy
create/destory zpool

Zpool properties

Each pool has customizable properties

NAME	PROPERTY	VALUE	SOURCE
zroot	size	460G	-
zroot	capacity	4%	-
zroot	altroot	-	default
zroot	health	ONLINE	-
zroot	guid	13063928643765267585	default
zroot	version	-	default
zroot	bootfs	zroot/ROOT/default	local
zroot	delegation	on	default
zroot	autoreplace	off	default
zroot	cachefile	-	default
zroot	failmode	wait	default
zroot	listsnapshots	off	default

Zpool Sizing

ZFS reservce 1/64 of pool capacity for safe-guard to protect CoW

RAIDZ1 Space = Total Drive Capacity -1 Drive
RAIDZ2 Space = Total Drive Capacity -2 Drives
RAIDZ3 Space = Total Drive Capacity -3 Drives
Dyn. Stripe of 4* 100GB= 400 / 1.016= ~390GB
RAIDZ1 of 4* 100GB = 300GB - 1/64th= ~295GB
RAIDZ2 of 4* 100GB = 200GB - 1/64th= ~195GB
RAIDZ2 of 10* 100GB = 800GB - 1/64th= ~780GB

http://cuddletech.com/blog/pivot/entry.php?id=1013

ZFS Dataset

ZFS Datasets

Two forms:

filesystem: just like traditional filesystem

volumn: block device

- ❑ nested
- ❑ each dataset has associatied properties that can be inherited by sub-filesystems
- ❑ controlled with single command
  - zfs

Filesystem Datasets

- Create new dataset with
  - zfs create <pool name>/<dataset name>
- New dataset inherits properties of parent dataset

Volumn Datasets (ZVols)

- Block storage
- Located at /dev/zvol/<pool name>/<dataset>
- Used for iSCSI and other non-zfs local filesystem
- Support “thin provisioning”

Dataset properties

```
NAME   PROPERTY          VALUE                  SOURCE
zroot  type              filesystem             -
zroot  creation          Mon Jul 21 23:13 2014  -
zroot  used              22.6G                  -
zroot  available         423G                   -
zroot  referenced        144K                   -
zroot  compressratio     1.07x                  -
zroot  mounted           no                     -
zroot  quota             none                   default
zroot  reservation       none                   default
zroot  recordsize        128K                   default
zroot  mountpoint        none                   local
zroot  sharenfs          off                    default
```

zfs command

zfs set/get <prop. / all> <dataset>
set properties of datasets

zfs create <dataset>
create new dataset

zfs destroy
destroy datasets/snapshots/clones..

zfs snapshot
create snapshots

zfs rollback
rollback to given snapshot

zfs promote
promote clone to the orgin of filesystem

zfs send/receive
send/receive data stream of snapshot with pipe

Snapshot

- Natural benefit of ZFS’ s Copy-On-Write design
- Create a point-in-time “copy” of a dataset
- Used for file recovery or full dataset rollback
- Denoted by @ symbol

Create snapshot

zfs snapshot tank/something@2015-01-02

- done in secs
- no addtional disk space consume

Rollback

```
# zfs rollback zroot/something@2015-01-02
```

- ❑IRREVERSIBLY revert dataset to previous state
- ❑All more current snapshot will be destroyed

Recover single file?

- hidden “.zfs” directory in dataset mountpoint
- set snapdir to visible

Clone

- “copy” a separate dataset from a snapshot
- caveat! still dependent on source snapshot

Promotion

- reverse parent/child relationship of cloned dataset and referenced snapshot
- so that the referenced snapshot can be destroyed or reverted

Replication

zfs send tank/somethin@123 | zfs recv ….

dataset can be piped over network
dataset can also be received from pipe

Performance Tuning

General tuning tips

- System memory
- Access time
- Dataset compression
- Deduplication
- ZFS send and receive

Random Access Memory

ZFS performance depands on the amount of system

- ❑recommended minimum: 1GB
- ❑4GB is ok
- ❑8GB and more is good

Dataset compression

- save space
- increase cpu useage
- increase data throughput

Deduplication

- requires even more memory
- increases cpu useage

ZFS send/recv

using buffer for large streams

- misc/buffer
- misc/mbuffer (network capable)

Database tuning

For PostgreSQL and MySQL users recommend using a different recordsize than default 128k.

PostgreSQL: 8k
MySQL MyISAM storage: 8k
MySQL InnoDB storage: 16k

File Servers

- disable access time
- keep number of snapshots low
- dedup only of you have lots of RAM
- for heavy write workloads move ZIL to separate SSD drives
- optionally disable ZIL for datasets (beware consequences)

Webservers

Disable redundant data caching

Apache

EnableMMAP Off

EnableSendfile Off

Nginx

Sendfile off

Lighttpd

server.network-backend="writev"

Cache and Prefetch

ARC

Adaptive Replacement Cache
- Resides in system RAM
  - major speedup to ZFS
  - the size is auto-tuned

Default:
- arc max: memory size - 1GB
- metadata limit: ¼ of arc_max
- arc min: ½ of arc_meta_limit (but at least 16MB)

Tuning ARC

- you can disable ARC on per-dataset level
- maximum can be limited
- increasing arc_meta_limit may help if working with many files

```
# sysctl kstat.zfs.misc.arcstats.size
# sysctl vfs.zfs.arc_meta_used
# sysctl vfs.zfs.arc_meta_limit
```

reference: http://www.krausam.de/?p=70

L2ARC

L2 Adaptive Replacement Cache

- is designed to run on fast block devices (SSD)
- helps primarily read-intensive workloads
- each device can be attached to only one ZFS pool

zpool add <pool name> cache <vdevs>
zpool add remove <pool name> <vdevs>

Tuning L2ARC

enable prefetch for streaming or serving of large files
configurable on per-dataset basis
turbo warmup phase may require tuning (e.g. set to 16MB)

vfs.zfs.l2arc_noprefetch
vfs.zfs.l2arc_write_max
vfs.zfs.l2arc_write_boost

ZIL

ZFS Intent Log

- ❑guarantees data consistency on fsync() calls
- ❑replays transaction in case of a panic or power failure
- ❑use small storage space on each pool by default

to speed up writes, deploy zil on a separate log device(SSD)
per-dataset synchonocity behavior can be configured

zfs set sync=[standard|always|disabled] dataset

File-level Prefetch (zfetch)

- analyses read patterns of files
- tries to predict next reads

Loader tunable to enable/disable zfetch: vfs.zfs.prefetch_disable

Device-level Prefetch (vdev prefetch)

- reads data after small reads from pool devices
- useful for drives with higher latency
- consumes constant RAM per vdev
- is disabled by default

Loader tunable to enable/disable vdev prefetch:

vfs.zfs.vdev.cache.size=[bytes]

ZFS Statistics Tools

sysctl vfs.zfs
sysctl kstat.zfs

using tools:

- zfs-stats: analyzes settings and counters since boot
- zfsf-mon: real-time statistics with averages

Both tools are available in ports under sysutils/zfs-stats

References

ZFS tuning in FreeBSD (Martin Matuˇska):
slides:
http://blog.vx.sk/uploads/conferences/EuroBSDcon2012/zfs-tuning-handout.pdf
video:
https://www.youtube.com/watch?v=PIpI7Ub6yjo

Becoming a ZFS Ninja (Ben Rockwood):
http://www.cuddletech.com/blog/pivot/entry.php?id=1075

ZFS Administration:
https://pthree.org/2012/12/14/zfs-administration-part-ix-copy-on-write/