MMP: Safer Pool Import With High Availability Clusters

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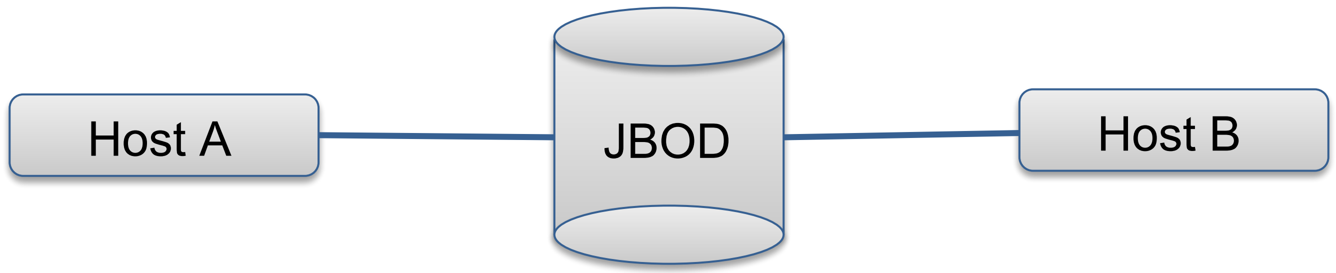
MMP: Problem Statement

Catastrophic corruption will occur if a ZFS pool is simultaneously imported on more than one host

- MMP prevents ZFS from importing a pool that is active on another host, under most circumstances
- Merged to ZFSonLinux, available from v. 0.7.0
  - https://github.com/zfsonlinux/zfs/pull/6073

MMP: Motivation



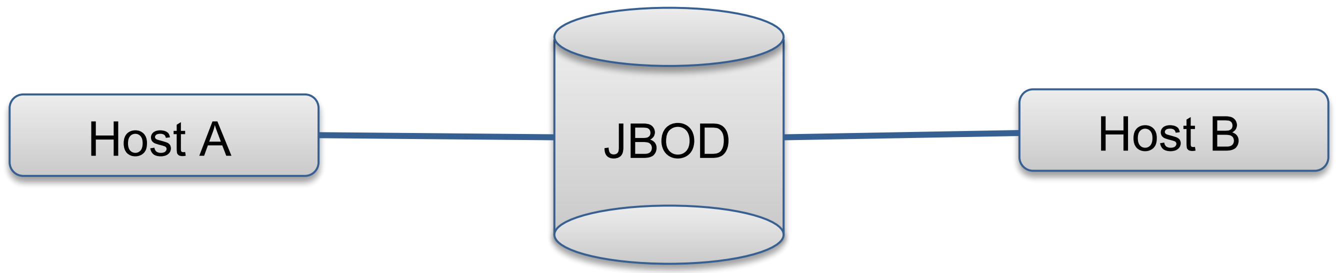
Our Use Case:

- Host B is a hot spare for Host A
- High Availability (HA) package starts services on B when A goes down
- **… but what if A is not really down?**

Existing Mechanisms are not sufficient

- Namespace check – scope is single host, Host B
- Hostid – Host B must always use “force” import, disabling this check
- HA package
  - May be misconfigured (we’ve done this)
  - May be fooled, e.g. by bad power control SW or HW (done this too)

MMP: Design Goals



Don’t Make Trouble

- Don’t change existing behavior – e.g. rollback still works
- Don’t degrade performance for non-failover users
- Preserve on-disk compatibility

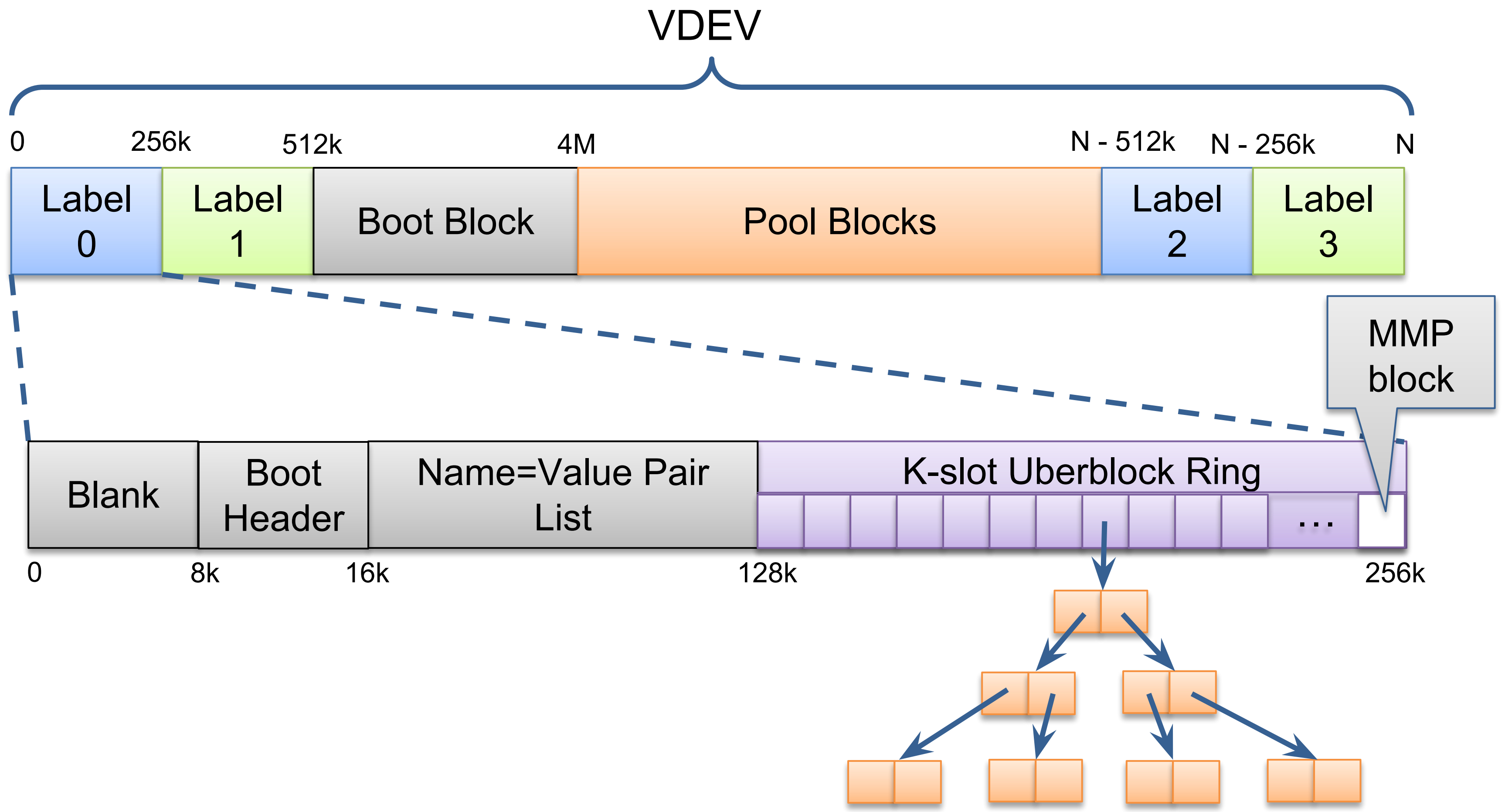
Reliable

- Simple configuration – no unsafe configurations
- Communicate via devices already shared
- Detect import even if some devices are not visible to Host B
- Enable automated single-node testing to catch regressions

Available Sooner Not Later

Low Performance Impact for failover users

MMP: Where do we look for activity?



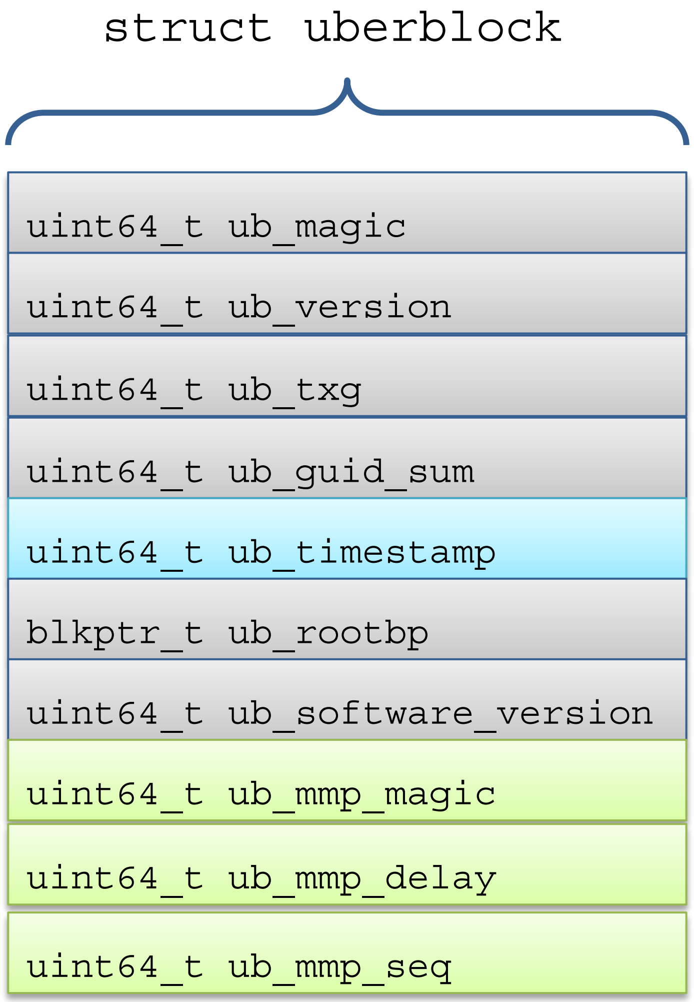
MMP: Options for signaling

DMU Blocks
- Importing pool (even R/O) for reading signal is unsafe (and unreliable)

Config nvlist
- Repeatedly overwriting likely results in inconsistent reads

Uberblock ring
- Code exists for reading and writing Uberblocks
- Import is not required for such reads
- Uberblocks written by txg sync are a free activity indicator
- Quiet pools need another mechanism for reflecting change
  - Forcing a new txg we may lose rollback
  - Writing over existing slots we may lose rollback
  - Partition Uberblock ring
    - Dedicate 1 slot to MMP Uberblock writes only
    - Dedicate remaining slots to txg sync Uberblock writes

MMP: Use Uberblocks for signaling



```
struct uberblock

uint64_t ub_magic
uint64_t ub_version
uint64_t ub_txg
uint64_t ub_guid_sum
uint64_t ub_timestamp
blkptr_t ub_rootbp
uint64_t ub_software_version
uint64_t ub_mmp_magic
uint64_t ub_mmp_delay
uint64_t ub_mmp_seq
```

ub_timestamp: wallclock time the uberblock was written, 1-second resolution

ub_mmp_magic: used to determine whether these fields are valid

ub_mmp_delay: at time this Uberblock was written, decaying average of time between successful MMP writes

ub_mmp_seq: currently unused, but intended to provide sub-second change detection

MMP: Existing Import Process (abridged)

Userspace	Kernel
Find devices, assemble partial config	
Tryimport ioctl w/config	Load Uberblock (latest txg & timestamp)
	Load MOS config via root block ptr
	Generate updated full config
	Fetch & verify other pool info
	Return full config nvlist & import info
Import ioctl w/config and flags	Do it all again
	Attempt import (Possibly roll back and retry)
	Return import info
Report result to user	

Notes: (1) Illumos has other code path(s) (2) Tryimport also used for ‘zpool status’

MMP: Complications

- Method
  - MMP thread writes Uberblocks on scheduled basis
  - Extend tryimport to return txg and timestamp
  - Userspace polls tryimport, watching for txg/timestamp change
- Problem
  - Host panics sometimes during tryimport, if the userspace-built config is stale when kernel loads MOS or compares MOS config with userspace config (could be many seconds old!)
  - Such user/kernel config coherency panics are not new; we chose to avoid them rather than trying to find and fix all such issues
- Solution
  - Perform poll in tryimport (kernel), and exit immediately if change is detected

MMP: Complications

- Method
  - MMP thread writes Uberblocks on scheduled basis
  - ✔ Tryimport polls for change (in kernel)
- Problem
  - What if there is a long delay between tryimport and import? Activity check result is no longer valid
- Solution
  - Perform poll in both tryimport (kernel) and import (kernel)

MMP: Complications

- Method
  - MMP thread writes Uberblocks on scheduled basis
  - ✔ Tryimport and import both poll for change (in kernel)
- Problem
  - User must wait 2x polling period for import to succeed
- Solution
  - If no activity detected, tryimport returns found txg and timestamp with config.
  - Userspace passes these values in when import ioctl issued; if they match what is found by import when the uberblock is loaded, still valid

MMP: Complications

- Method
  - MMP thread writes Uberblocks on scheduled basis
  - Tryimport polls for change
  - ✔ Tryimport records txg and timestamp
  - ✔ Import polls if txg and timestamp do not match
- Problem
  - What if user settings for MMP write period differ on Host A and B?
  - What if there are large I/O delays due to some problem?
- Solution
  - Host A records the average time between MMP writes at the end of the Uberblock.
  - Host B reads that to compute required polling period

MMP: Complications

- Method
  - MMP thread writes Uberblocks on scheduled basis
  - Tryimport polls for change
  - Tryimport records txg and timestamp
  - Import polls if txg and timestamp do not match
  - ✔ Polling period based on MMP write period recorded in Uberblock
- Problem
  - What if two hosts attempt to import pool at the same time?
- Solution
  - Add a small random term when calculating the polling period. One will finish sooner and the others will see its MMP writes
  - (caveat) If the pool was cleanly exported this is defeated – needs thought

MMP: Complications

- Method
  - MMP thread writes Uberblocks on scheduled basis
  - Tryimport polls for change
  - Tryimport records txg and timestamp
  - Import polls if txg and timestamp do not match
  - Polling period based on MMP write period recorded in Uberblock
  - ✔ Polling period includes random term for simultaneous imports
- Problem
  - How do we avoid all this for non-failover configurations?
- Solution
  - We cannot detect whether the storage is shared, so the user must tell us.
  - Introduce a property, multihost="on" means we perform activity test
    - We can also check that hostid is set when property set

MMP: Complications

- Method
  - MMP thread writes Uberblocks on scheduled basis
  - Tryimport polls for change
  - Tryimport records txg and timestamp
  - Import polls if txg and timestamp do not match
  - Polling period based on MMP write period recorded in Uberblock
  - Polling period includes random term for simultaneous imports
  - ✔ Multihost property allows user to turn MMP on
- Problem
  - Host B cannot tell whether the property is on before import
- Solution
  - When the property is off, we zero the MMP fields in Uberblock
  - Host B polls for change if MMP fields are nonzero

MMP: Merged Implementation

- Method
  - MMP thread writes Uberblocks on scheduled basis
  - Tryimport polls for change
  - Tryimport records txg and timestamp
  - Both tryimport and import skip poll if MMP fields in Uberblock zeroed
  - Import polls if txg and timestamp do not match ones from tryimport
  - Polling period is based on MMP write period recorded in Uberblock
  - Polling period includes random term for simultaneous imports
  - Multihost property allows user to turn MMP on
  - ✔ Zero MMP fields in Uberblock when multihost=off
- And…
  - MMP blocks are written to randomly selected leaves and labels at frequency (1000 * zfs_multihost_interval / # vdevs) Hz
  - Pool is suspended if (time since last successful MMP write) > (1000 * zfs_multihost_interval * zfs_multihost_fail_intervals)

  (zfs_multihost_interval is in milliseconds)

MMP: Testing

- Challenges
  - Namespace checks prevent two imports on same node
  - Hostid kernel sees will be the same for both import attempts
  - Multi-node testing much more difficult, even with VMs
- Solution: ztest is the “remote host”
  - Separate namespace since it runs entirely in userspace
  - Altered to allow hostid to be set via environment variable
  - Added option to skip some tests that halt activity to the pool

MMP: Limitations / Future Work

- MMP is defeated by long delays in I/O
  - Algorithm assumes import is safe after some period but there is no guarantee this is true
  - For example admin disconnnects a SAS cable, replaces after 30 sec
  - HW/SW problems can create similar delays
- No ongoing (post-import) check
- No protection when a pool is suspended
    - Host A imports pool
    - Host A encounters errors and the pool is suspended
    - Host B imports the pool while there is no activity
    - Host A admin issues ‘zpool clear’ and resumes I/O
- MMP offers no protection to ‘zpool create/add/attach/replace’
  - For example, if a new device (no label) is added to two pools at the same time
  - The window of vulnerability is small as label writes happen early in the process
- Zpool labelclear does not check for activity

MMP: Questions?

Credits

Multi-Modifier protection for ZFS was developed by Lawrence Livermore National Laboratory.

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The design built on an earlier project, with a design authored by Ricardo Correia in 2009.

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