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Strategies for running unmodified filesystems on SMR drives

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Challenges when using SMR drives

Challenges when using SMR

- Partitioning
  - most end-users are used to partitioning devices
- Uninitialized READ
  - ZBC per default will return I/O errors when reading from uninitialized sectors
- Zone alignment: SMR devices require or at least benefit greatly from aligning data to zones

Partitioning

- GPT partitioning required
- Most partitioning tools create a GPT backup sector at the end of the disk
- Write needs to be buffered if last zone is a Sequential Write Required zone.

Uninitialized READ

- If 'UNSZW' bit isn't set any READ to an uninitialized zone will return I/O errors
- None of the drivers currently existing are aware of this pecularity
- I/O errors will be presented to the user upon first access
- I/O needs to be buffered to prevent detrimental user experience

Zone alignment

- Most filesystems have a fixed disk layout
  - All filesystems require to have certain bits at specific, pre-defined location. This location is part of the on-disk format and cannot be changed.
  - Some filesystems either have a sequential allocation algorithm (btrfs, ZFS), or allow to specify one (ext4, xfs)
- Filesystems need to be aware of the zone layout

Sequential Write requirement

- Host-aware devices require sequential writes
- Some filesystems provide matching capabilities
  - Btrfs always tries to write sequentially, due to its CoW nature.
  - Ext4 has an SMR-optimized allocation strategy (packed_meta_blocks), which should allow for sequential writes
  - XFS at the moment is not capable of ensuring sequential writes

Challenges for OS vendors

- Filesystem layout cannot be changed
  - On-disk format is required to be stable
  - Adapting filesystems possible if on-disk format isn't changed
- Adding new filesystems very unlikely
  - Only with compelling use-case
  - Not possible with existing distributions

Challenges for Linux

- SMR host-aware patches have been posted to upstream
  - Held by procedural issues (touching several subsystems)
  - ATA Sense code handling under discussion
- SMR host-managed patches pending
  - Core functionality already in 4.1
  - Extended functionality pending

General considerations

- Host-aware (and device-managed) implementations require only limited support from the OS
  - Data alignment
  - Reset Write Pointer handling
- Focus on host-managed devices

Strategies for SMR drives

Possible strategies

- Modify filesystems to match SMR capabilities
  - Requires updates to existing or entirely new filesystems
  - On-disk format likely to be changed
  - Additional support overhead for OS Vendors
  - Unknown stability

Possible strategies

- Remap unaligned I/O to CMR zones
  - Requires remapping of the entire disk
  - New on-disk format
  - Remapping functionality required for disk access
- Presentation by Albert Chen

Possible strategies

- Cache non-sequential I/O:
  - Cache entire zones
  - High memory consumption
  - On-disk format unchanged
  - No additional functionality required for access

Caching non-sequential I/O

Caching non-sequential I/O

- Per-zone writeback cache
- Zones are being read in upon access
- Two-stage writeout:
  - RESET WRITE Pointer
  - Write zone data
- Zone cache is kept until expiry or memory pressure

Caching non-sequential I/O

- Zone cache eviction:
  - User-selectable cache expiration time
  - User-selectable upper bound on number of caches
- LRU eviction:
  - Select LRU cache
  - Flush old cache contents
  - Read in new data
- Possible cache trashing depending on I/O load

Cache exceptions

- Caching of all I/O leads to heavy cache usage
  - Aligned writes can be exempted
  - Reads to initialized areas can be exempted
  - Reads to non-initialized areas can be zero-filled
  - Writes beyond WP can be zero-extended

Test results

Filesystem tests

- 'Real-life' scenario for testing:
  - Create filesystem
  - Mount filesystem
  - Copy linux kernel tarball
  - Unpacking linux kernel
  - Applying 5949 patches
  - Unmount filesystem

Filesystems for testing

- Tested with btrfs and ext4
  - Xfs suffers from heavy cache trashing
  - Xfs needs to be modified for SMR
- Standard options for btrfs
- Ext4 tweaking:
  - packed_meta_blocks,flex_bg
  - Aligned 'stride' and journal size/location to zones

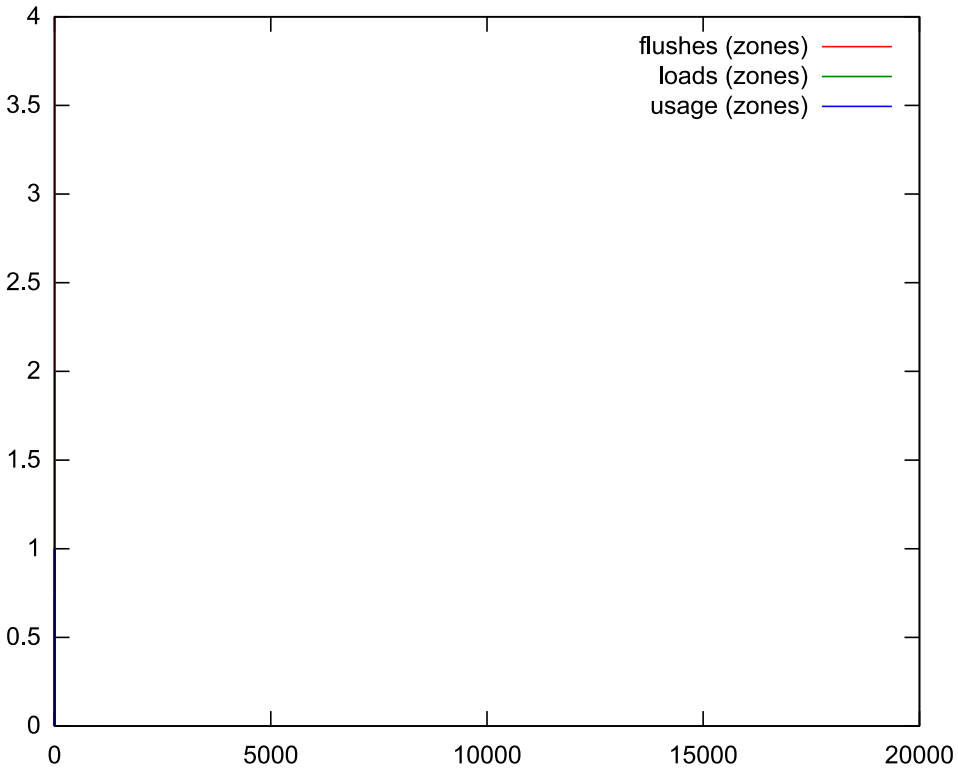
Btrfs results

	Standard disk	SMR disk
Mkfs	0.2 sec	1.4 sec
Mount	0.2 sec	0.4 sec
Cp	0.2 sec	0.4 sec
Tar	17.2 sec	17.6 sec
Patch	133.1 sec	136.0 sec
Umount	2.2 sec	12.3 sec

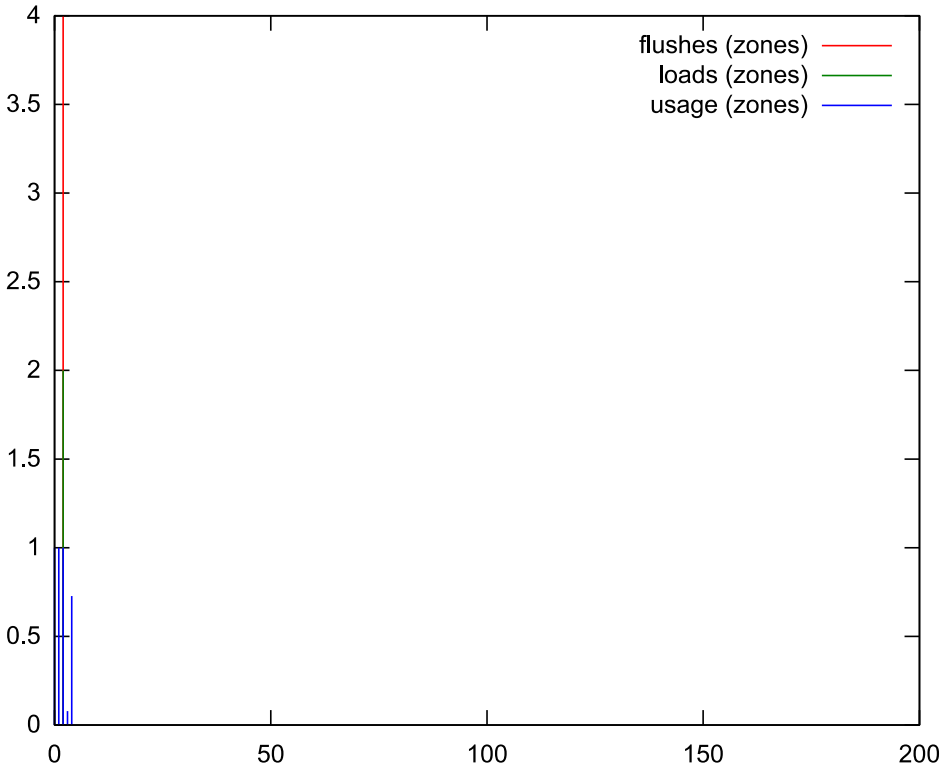
ext4 results

	Standard disk	SMR disk
Mkfs	3 sec	(28 sec)
Mount	0.4 sec	0.4 sec
Cp	4.8 sec	4.8 sec
Tar	13.6 sec	13.8 sec
Patch	135.1 sec	133.0 sec
Umount	3.1 sec	41.8 sec

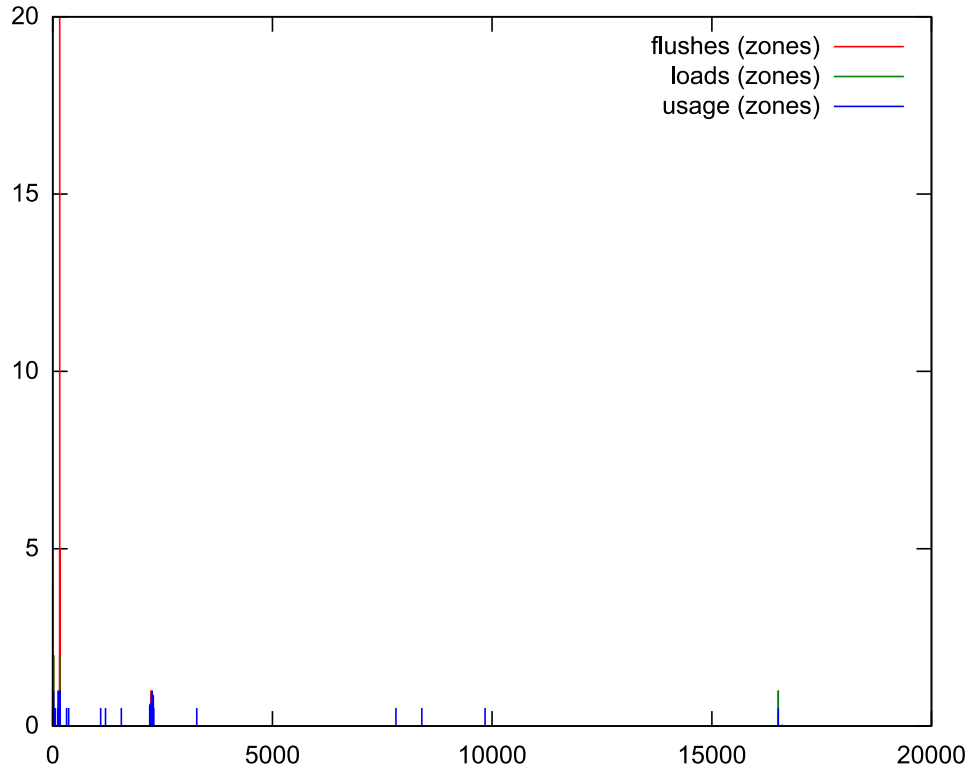
Btrfs zone usage



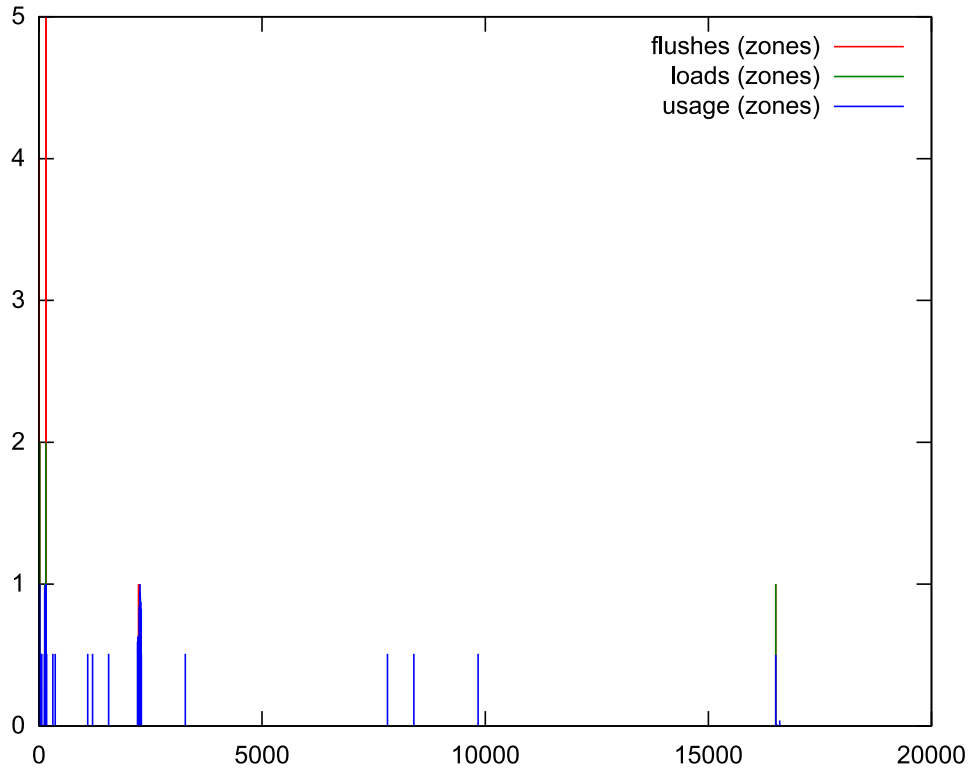
Btrfs zone usage



Ext4 zone usage



Ext4 zone usage



Summary

Result summary

- SMR writeback caching achieves performance comparable to native usage
- Cache efficiency on ext4 better than on btrfs:
  - 46% vs. 78% aligned cache accesses
- Low zone usage on btrfs offsets reduced cache efficiency

Btrfs result summary

- Btrfs operation matches SMR parameters very closely:
  - Low concurrent zone usage: nearly all writes are aligned
  - Low overall zone usage: nearly all writes are sequential
- High number of misaligned write accesses; points to an issue with btrfs itself

Ext4 result summary

- Less efficient zone usage
- Performance comparable to btrfs
- High number of cached zones
  - Writeback might be an issue
- Frequent cache flushes
  - FUA causes cache to be flushed

Misaligned I/O handling

- Misaligned I/O (ie I/O beyond the write pointer) quite common
- Implemented with normal WRITE commands, writing NULLs
- Switch to WRITE SAME might increase performance

Summary

- Using a per-zone writeback cache allows the use of unmodified filesystems
- Suitable for btrfs and ext4
- Performance comparable to native filesystem usage
- Increased memory usage

Thank you!