Reclaiming Good Transactions from a Corrupt Journal

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Motivation

Persistent storage media is becoming larger and denser.

There is increased media corruption and hardware unreliability.

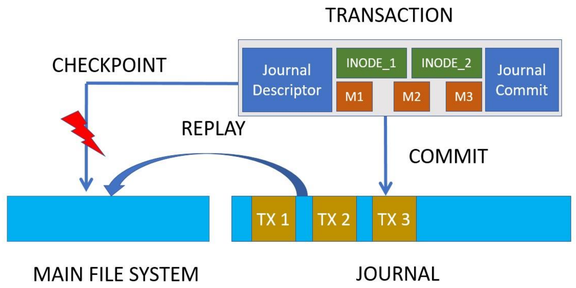
Storage systems need robust recovery techniques.

Current File System recovery techniques - replication and journaling.

Journaling

Journaling removes time consuming ***fsck*** run on unclean shutdown.

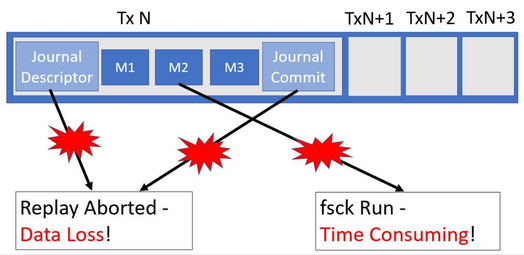
It also writes metadata to a linear log which increases performance.



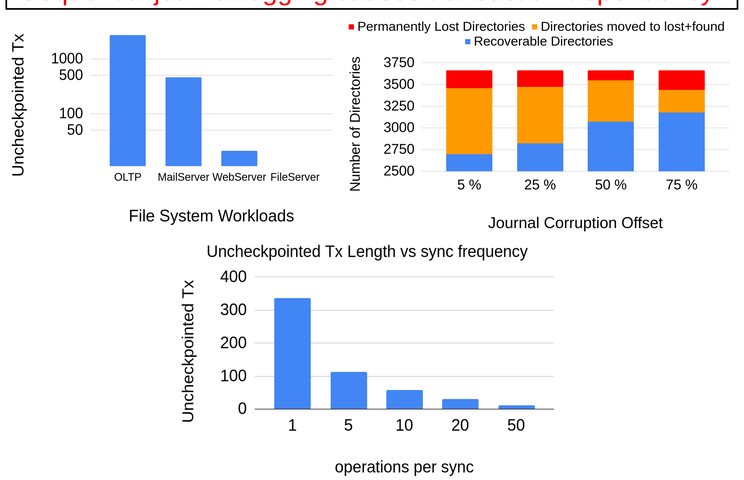
Problem

Journal header or Journal commit corruption leads to data loss.

Journal metadata corruption leads to time consuming ***fsck*** run.



Sequential journal logging causes transaction dependency!



Solution: Sub-Journaling

Log atomic file system updates into different sub-journals.

Each sub-journal can be replayed ***independent*** of the other sub-journal.

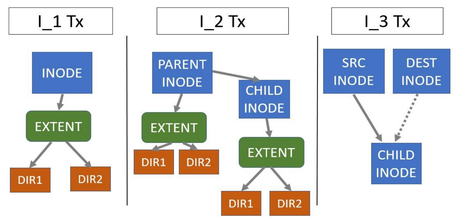
File system remains consistent after any sub-journal replay.

Categorize Transaction Updates

Number of Inodes updated

File System operation	0 inodes (I_0 Tx)	1 inode (I_1 Tx)	2 inodes (I_2 Tx)	3 inodes (I_3 Tx)
	mount	truncate	create	rename
	access	chmod	rmdir	
	stat	chown	mkdir	
	chroot	utimes	link	
	chdir	read	symlink	
	open	write	unlink	

Inodes updated by same transaction have parent-child relationship



Invariants Maintained

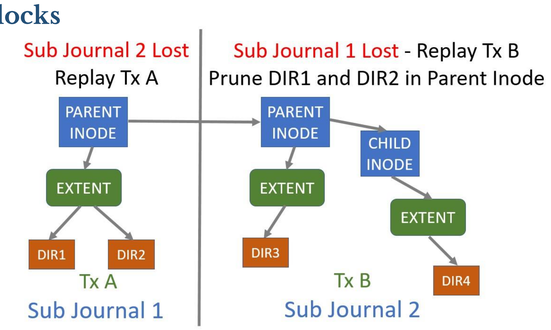
Map all metadata of one transaction to one sub-journal.

Map metadata of one inode to one sub-journal.

Remap parent inode to child inode's sub-journal for I_2 Tx and I_3 Tx.

Recovery after Crash

Inode Blocks



Extent and Directory Block

Prune ***extents*** containing lost directories.

Group Descriptor and Bitmaps

Regenerate after restoring other metadata from available sub-journals.

Deleted Inodes

re-allocation is delayed until checkpoint.

Orphan list is sent to each sub-journal.

Superblock

Record in each sub-journal

Implementation

ext4

1 LOC changed

jbd2_journal_dirty_metadata (inode_no)

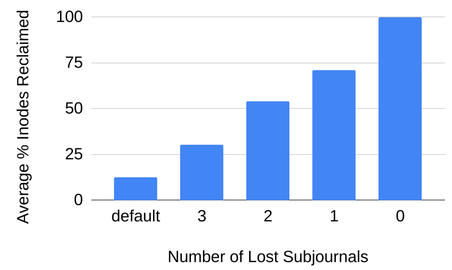
Register Transaction category - I_0 Tx, I_1 Tx, I_2 Tx, I_3 Tx

jbd2

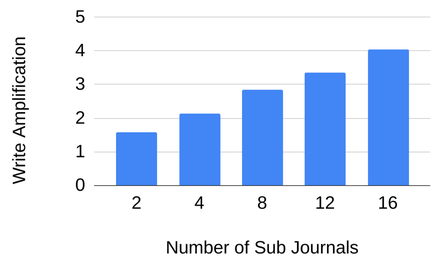
700 LOC added

In Memory Hash Maps	On Disk Structures
<Tx_Handle - Sub-Journal>	Add to Transaction Descriptor Block
<Tx_Handle - Journal Blocks>	<Inode - Sub-Journal> Map
<Tx_handle - Inode>	<Metadata block - Sub-Journal> Map

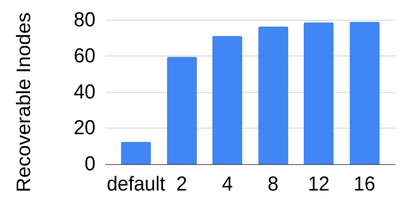
Results



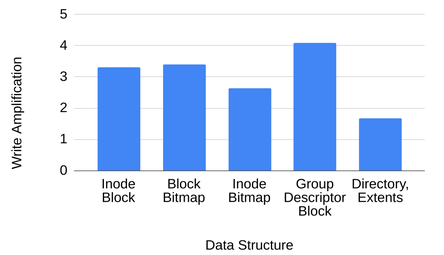
Recoverable inodes for a 4 sub-journal file system with varying lost sub-journals.



Sub-journaling technique incurs Write Amplification with more sub-journals.



Recoverable Inodes after 1 sub-journal loss with different sub-journal configurations.



Write Amplification Data Structure distribution for 4 sub-journal file system.

Future Work

Reduce Write Amplification by optimizing bitmap and descriptor block logging.

Handle delete operations by tracking orphan inodes across sub-journals.

Application crash consistency - journal one application transactions in one sub-journal.

Verify sub-journaling and journaling equivalence.

Related Work

SPANFS – Separates transactions into static domains based on Block Groups.

iJournaling – Fine Grained Journaling focusses on improving fsync() performance.

High Performance Transaction processing aims to improve multi core scalability.

Application Level Crash Consistency provides isolated streams for each application.