次世代文件系统Btrfs介绍

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Agenda

- What is Btrfs?
- Why is Btrfs needed?
- Which features does Btrfs include?
- How is Btrfs implemented?
- What did we do for Btrfs?
- How do I use Btrfs?

What is Btrfs？

- Btrfs is a new copy on write file system for Linux aimed at implementing advanced features while focusing on fault tolerance, repair and easy administration. (From Btrfs Wiki)

- Initially developed by Oracle, licensed under the GPL.

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Why is Btrfs needed?

- Disadvantages of the traditional file system
  - The limit of the file size and the file system size
  - Very bad augmentability
  - Very bad data integrity
  - No SSD support
  - …
- The stress of ZFS – the next generation file system on Solaris

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Which features does Btrfs include?

- Extent based file storage
- 64Bits based space management
- Dynamic inode allocation
- COW(Copy On Write) based transaction
- Checksums on data and metadata
- Integrated multiple device support
- Delayed space allocation
- Online Defragment

Which features does Btrfs include?

- Inline file
- Tree Log
- Compression
- SSD support
- Seed Device support
- Snapshot
- Subvolume

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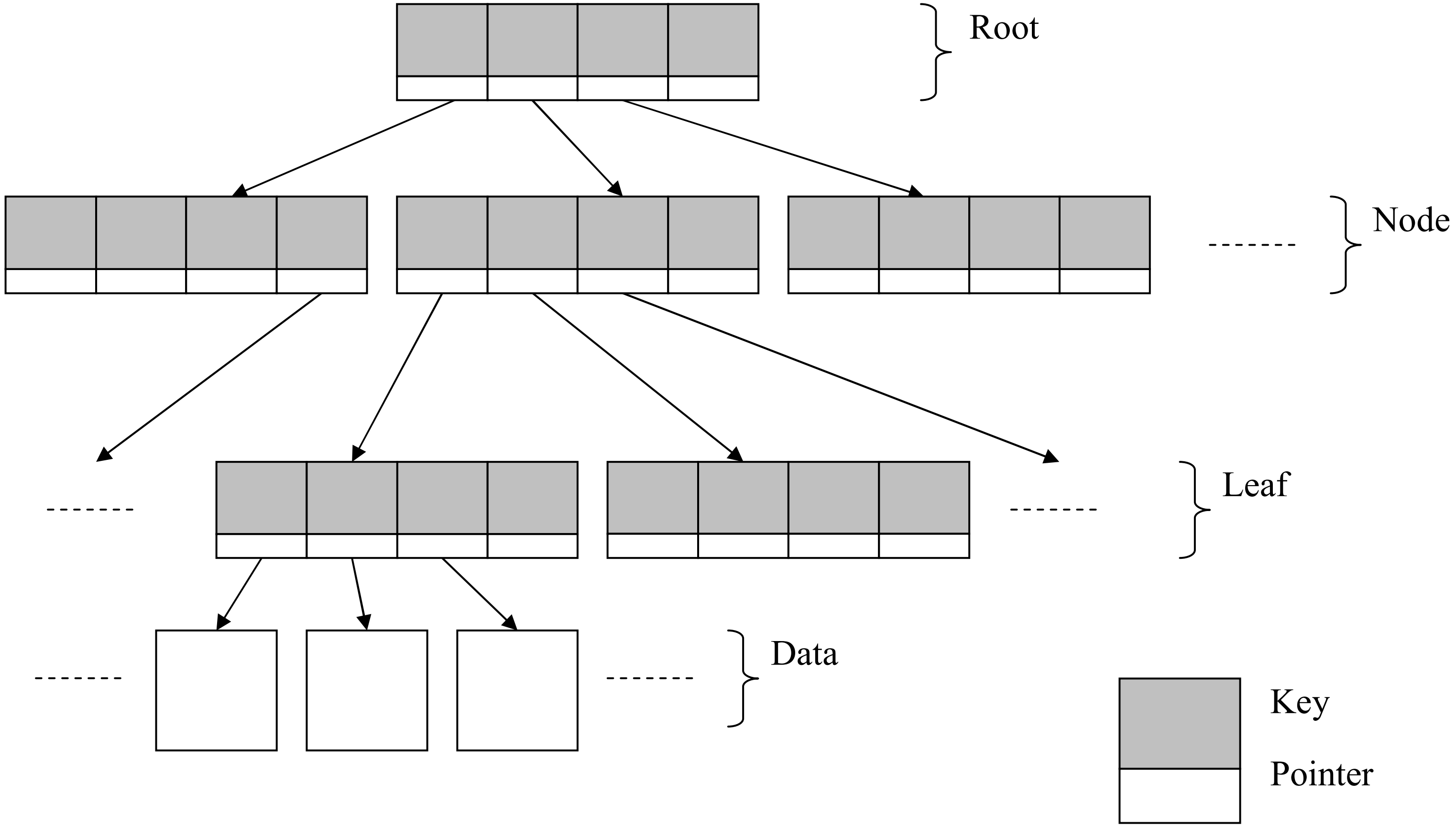
How is Btrfs implemented?

- Basis of Btrfs – B+ tree
- On-disk data structure
- Implementation of the features

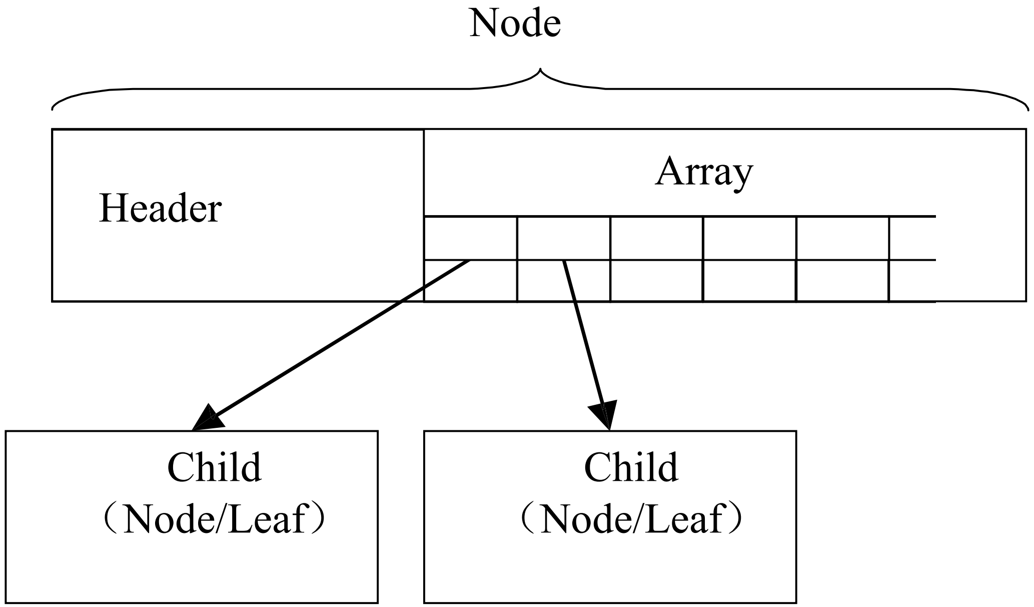
Basis of Btrfs – B+ tree

- Components of B+ tree



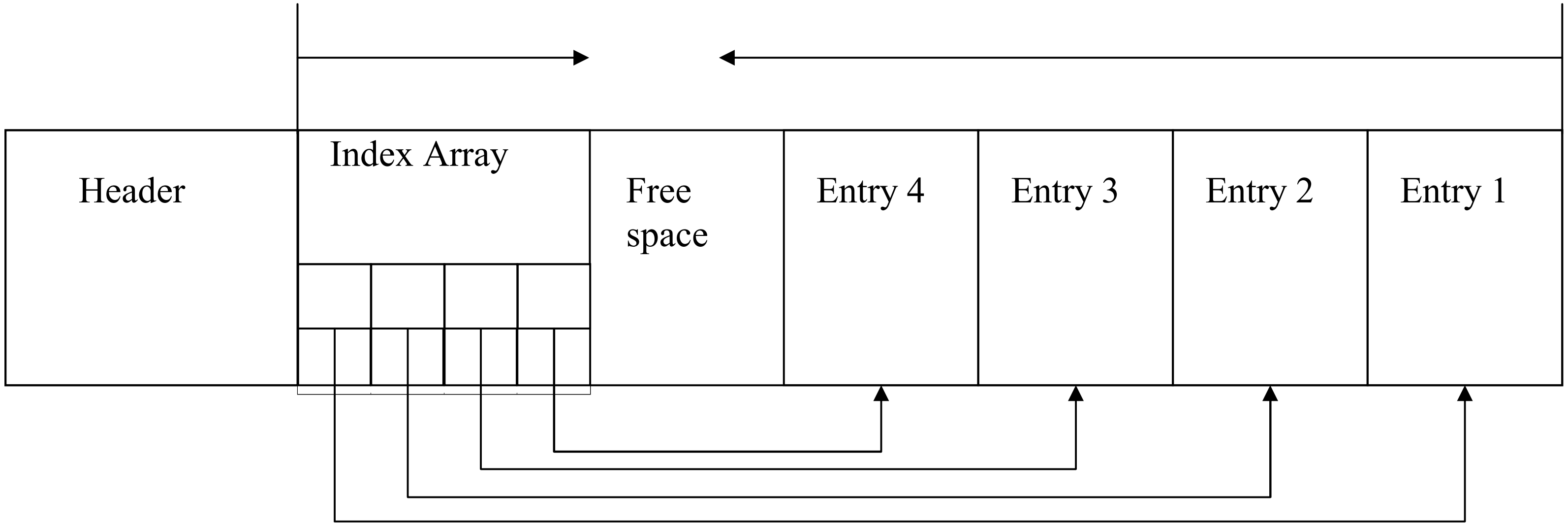
Basis of Btrfs – B+ tree

- Components of the internal node



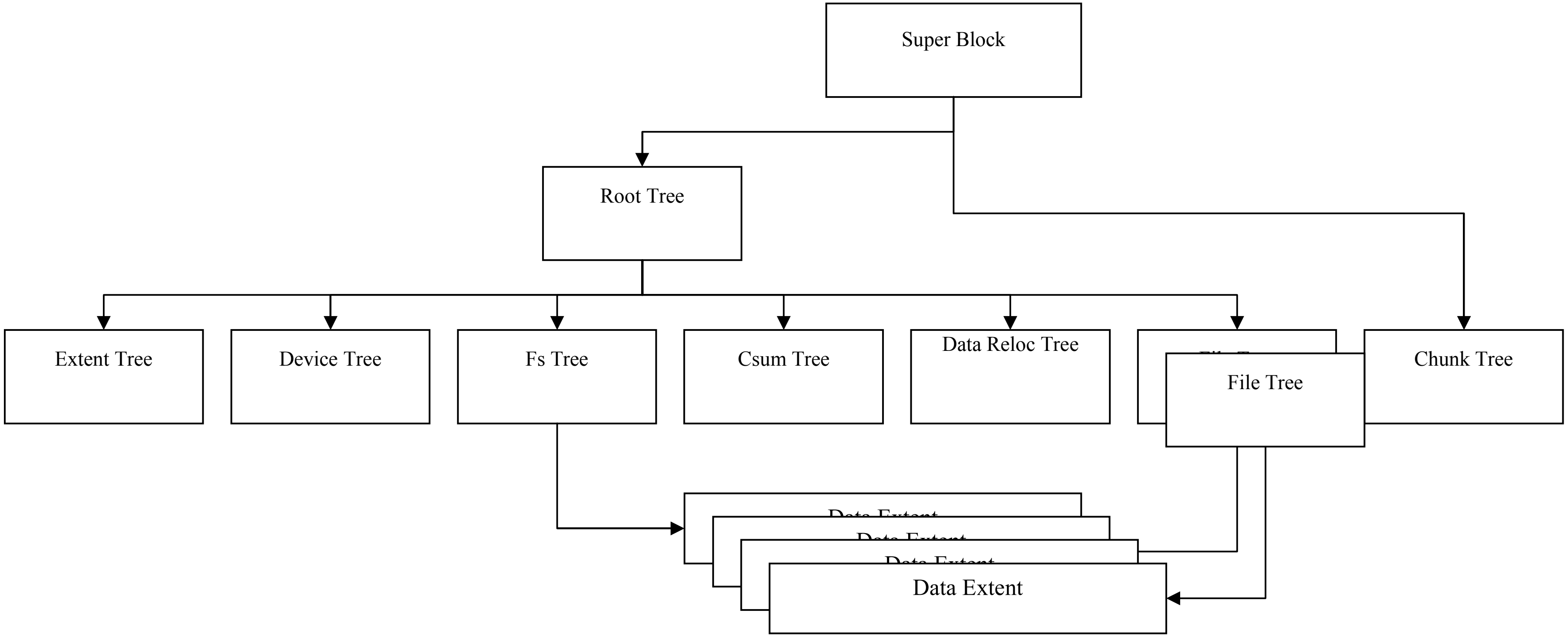
Basis of Btrfs – B+ tree

- Components of the leaf



On-disk data structure

- Main construction



On-disk data structure

- Root Tree
  - btrfs_root_item
  - btrfs_root_ref
  - …
- Chunk Tree
  - btrfs_dev_item
  - btrfs_chunk
- Device Tree
  - btrfs_dev_extent

On-disk data structure

- Extent Tree
  - btrfs_block_group_item
  - btrfs_extent_item
  - btrfs_tree_block_ref
  - btrfs_extent_data_ref
  - btrfs_shared_block_ref
  - btrfs_shared_data_ref

On-disk data structure

- Fs/File Tree
  - btrfs_inode_item
  - btrfs_inode_ref
  - btrfs_dir_index
  - btrfs_dir_item
  - btrfs_extent_data

On-disk data structure

- Csum Tree
  - btrfs_extent_csum

- Data Relocation Tree
  - btrfs_inode_item
  - btrfs_extent_data

Implementation of the features

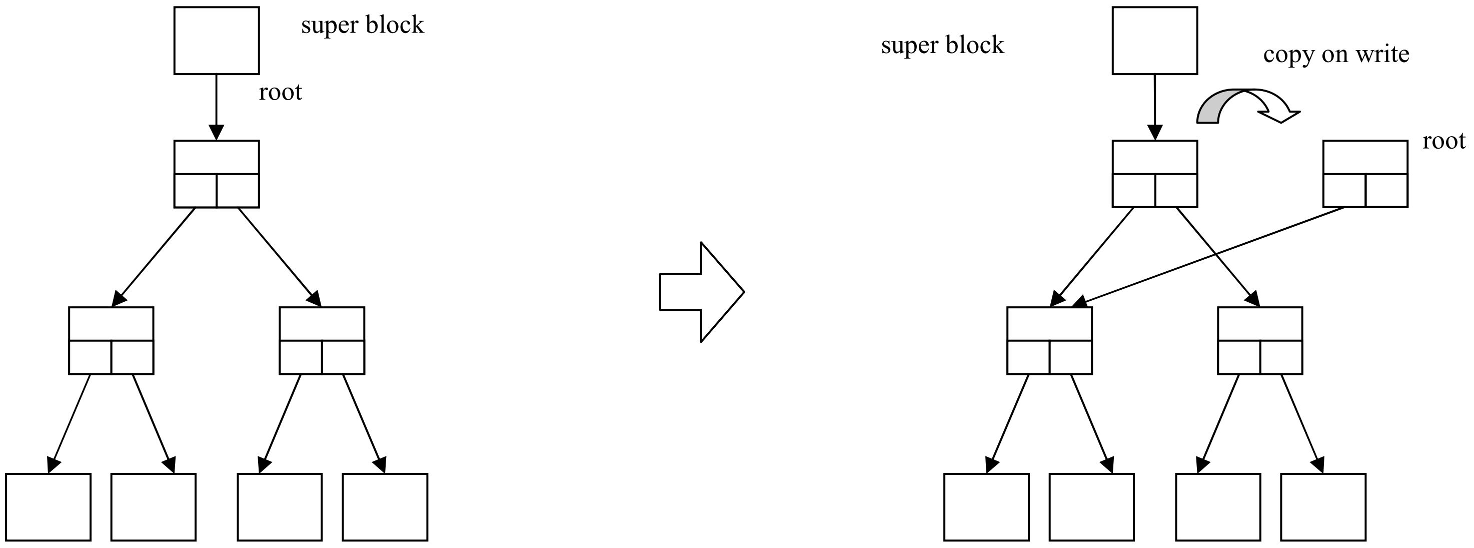
- Extent based file storage
  - [start, len]
  - Extent + Bitmap
- 64Bits based space management
  - 64Bits vs 32Bits(Ext3)/48Bits(Ext4)
- Dynamic inode allocation
  - Insert a inode item into Fs/File tree

Implementation of the features

- COW based transaction
  - COW: Copy on Write. Copy the data before writing. Used for forking child task in the kernel
  - guarantee the data integrity on crash, be similar with JBD layer of Ext3/4

Implementation of the features

- COW based transaction

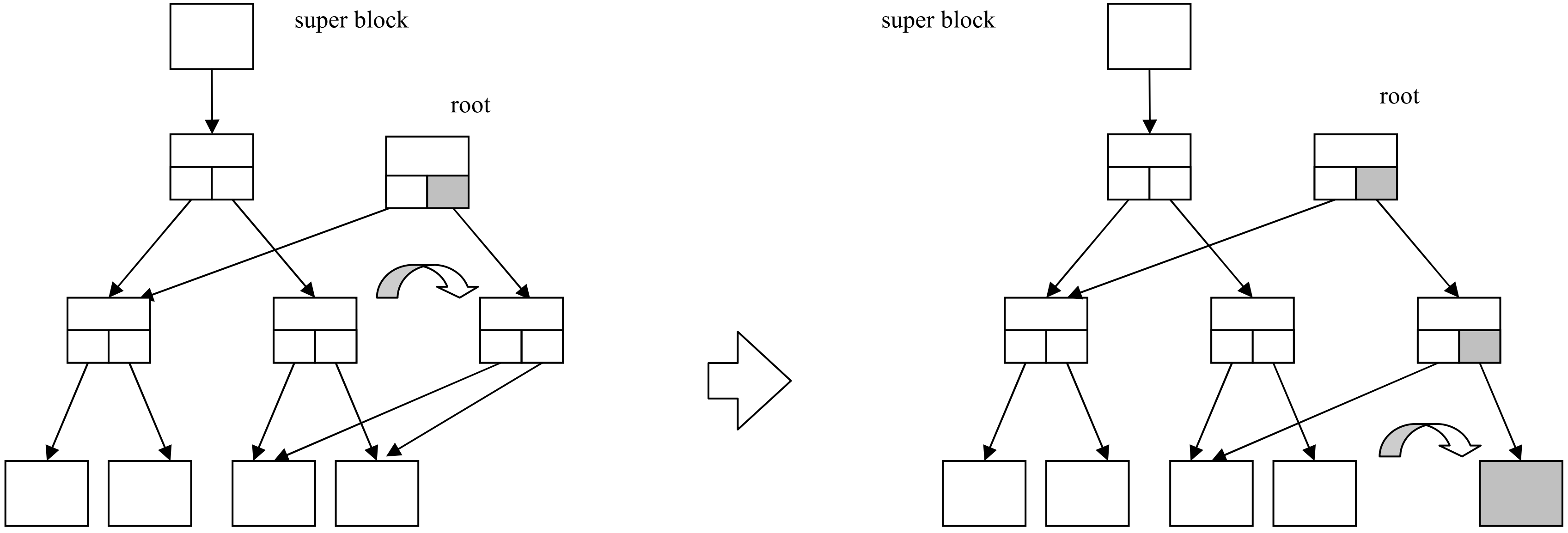


step 0) initial status(start transaction)

step 1) Update the root

Implementation of the features

- COW based transaction

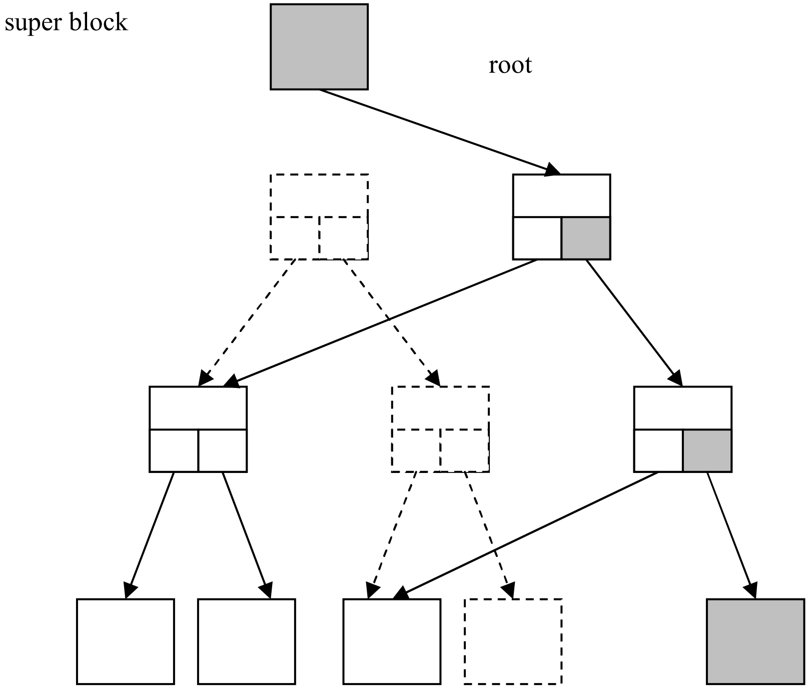


step 2) Update the node

step 3) Update the leaf

Implementation of the features

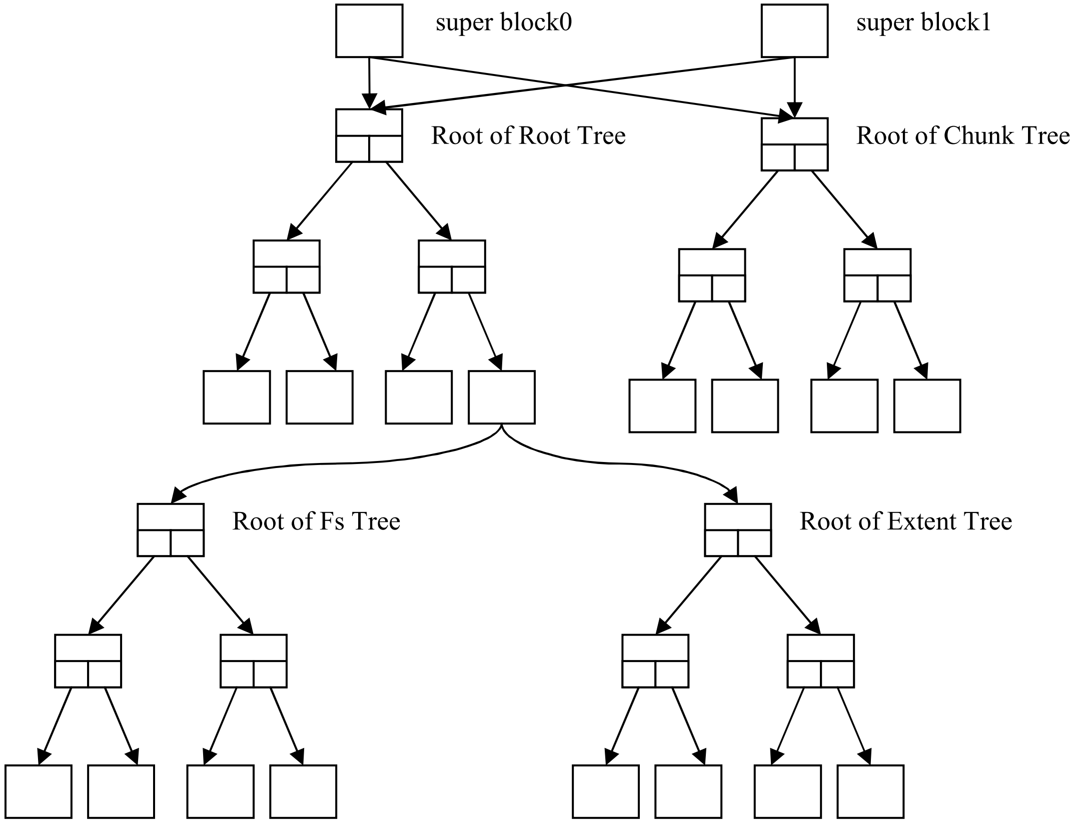
- COW based transaction



step 4) Update the super block(submit the transaction)

Implementation of the features

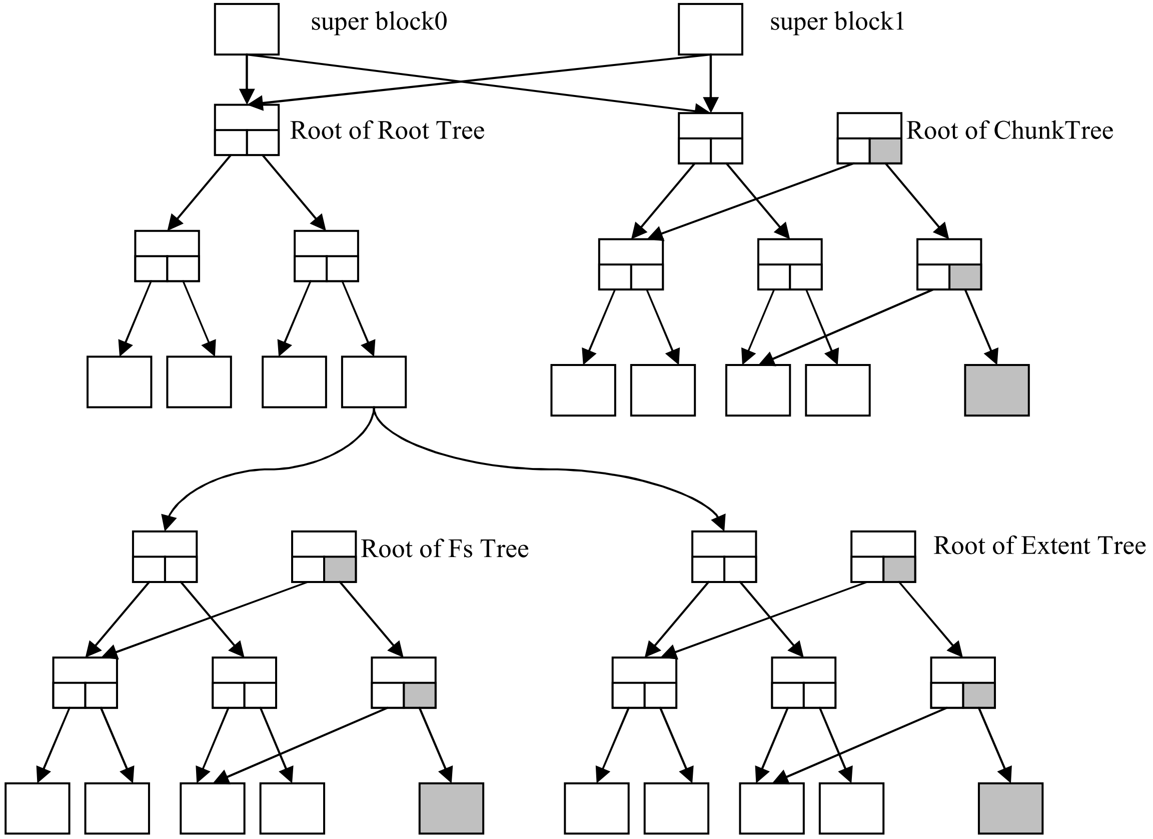
- COW based transaction



step 0) initial status(start transaction)

Implementation of the features

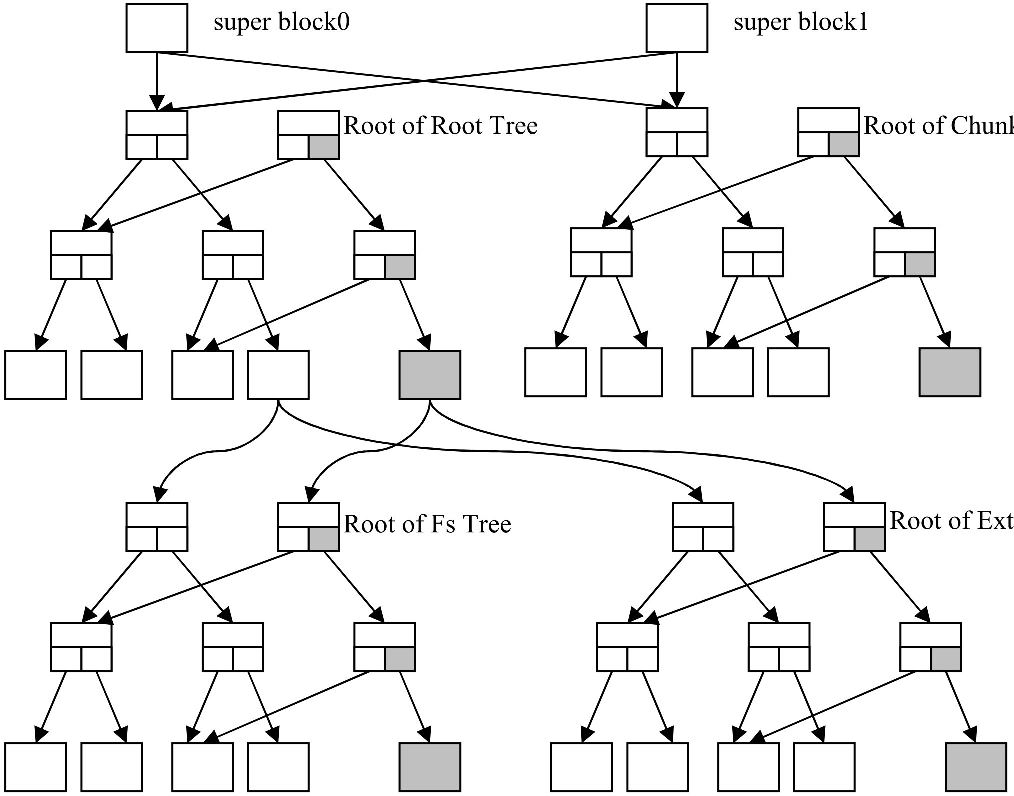
- COW based transaction



step 1) Update metadata in fs tree, extent tree and chunk tree

Implementation of the features

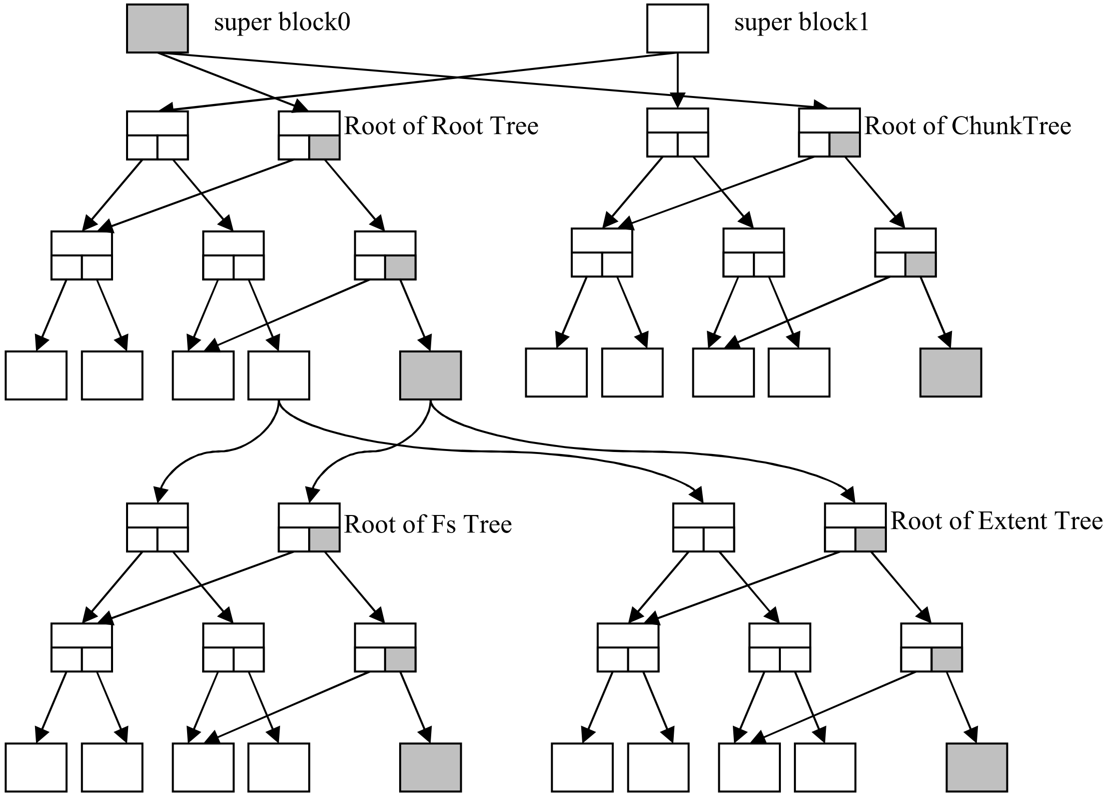
- COW based transaction



step 2.1) Update root tree(The 1st step of transaction commit)

Implementation of the features

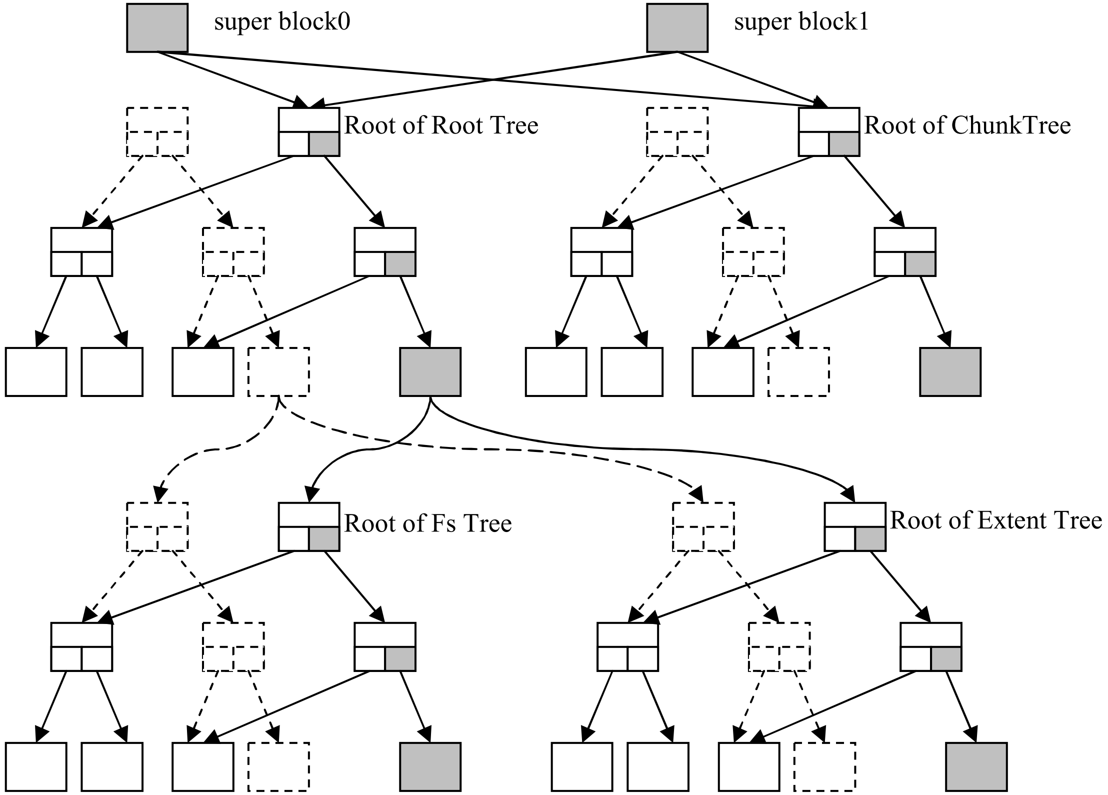
- COW based transaction



step 2.2) Update the 1st super block(The 2nd step of transaction commit)

Implementation of the features

- COW based transaction



step 2.3) Update the 2st super block(The 3st step of transaction commit)

Implementation of the features

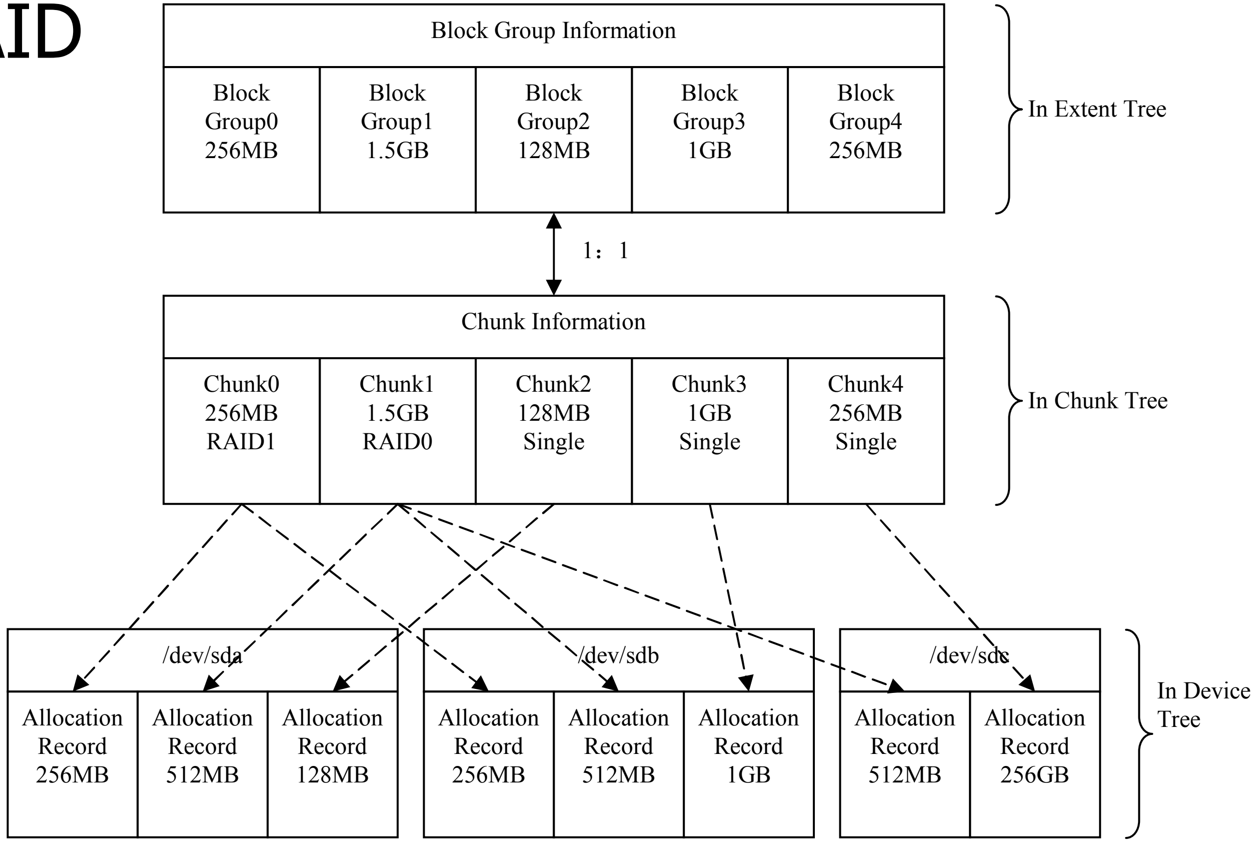
- Checksums on data and metadata
  - Data
    - Read: read checksum data from csum tree before submitting I/O request, do checksum after I/O request ends
    - Write: calculate checksum data before submitting I/O request, insert the checksum data into csum tree after I/O request ends

Implementation of the features

- Checksums on data and metadata
  - Metadata
    - Read: read metadata of a leaf or node, and get the checksum data from the header of the leaf/node, do checksum
    - Write: calculate checksum data of the leaf/node, put the checksum into the header of the leaf/node, write the leaf/node into the disk

Implementation of the features

- Integrated multiple device support
  - Soft RAID



Block Group Information

Block Group0 256MB

Block Group1 1.5GB

Block Group2 128MB

Block Group3 1GB

Block Group4 256MB

In Extent Tree

1：1

Chunk Information

Chunk0 256MB RAID1

Chunk1 1.5GB RAID0

Chunk2 128MB Single

Chunk3 1GB Single

Chunk4 256MB Single

In Chunk Tree

/dev/sda

Allocation Record 256MB

Allocation Record 512MB

Allocation Record 128MB

/dev/sdb

Allocation Record 256MB

Allocation Record 512MB

Allocation Record 1GB

/dev/sdc

Allocation Record 512MB

Allocation Record 256GB

In Device Tree

Implementation of the features

- Integrated multiple device support
  - Add/remove devices
    - Two lists: one is used to manage the devices that in the file system including read-only devices; the other is used to manage the allocable devices
    - Open/Close the device
    - Initialize the device/relocate the data

Implementation of the features

- Delayed space allocation
  - Space reservation
  - Allocate the space when doing write-back, not before writing data into the cache.
  - Advantage: reduce the fragment.

Implementation of the features

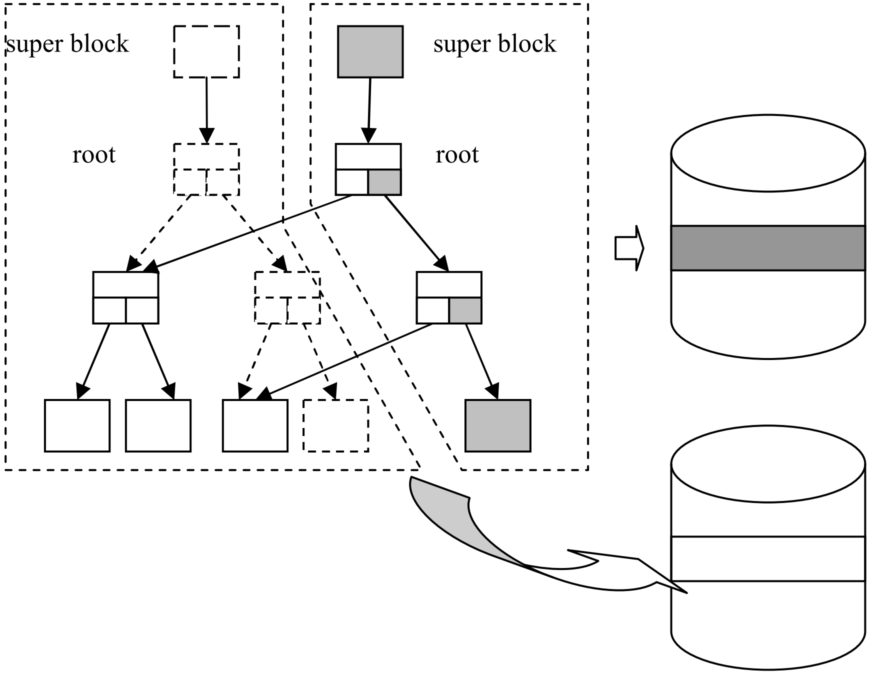
- Online Defragment
  - Use the delayed space allocation
  - Read the fragment into the cache, and mark the dirty flag
  - Write back the dirty data in the cache

Implementation of the features

- Inline file
  - Store the file data into Fs/File tree after the relative btrfs_extent_data
  - Read the file data when reading the metadata
- Compression
  - zlib/LZO
  - Read: uncompress the data after ending the I/O request and then copy the uncompressed the data into the cache.
  - Write: compress the data before the space allocation when doing write-back.

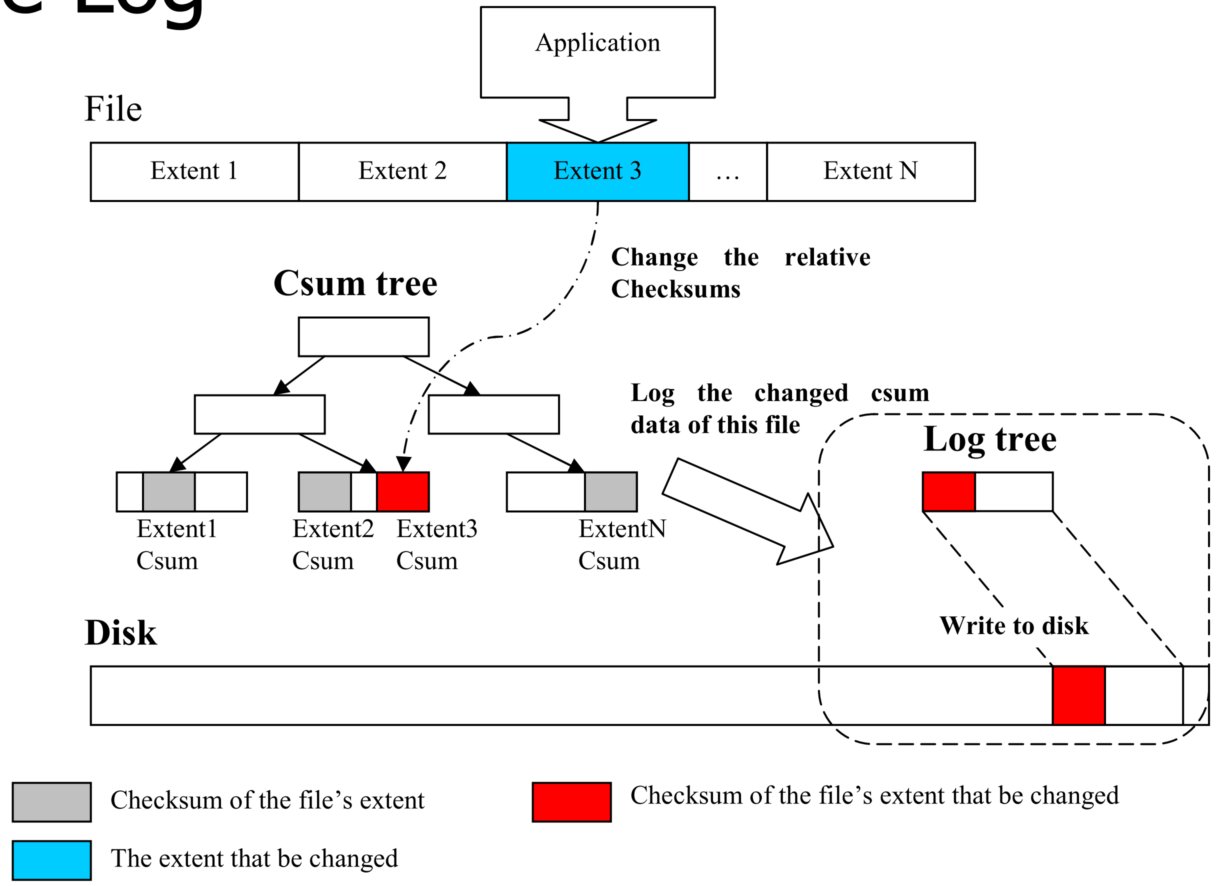
Implementation of the features

- SSD support
  - Free space cluster
- Seed Device support



Implementation of the features

- Tree Log

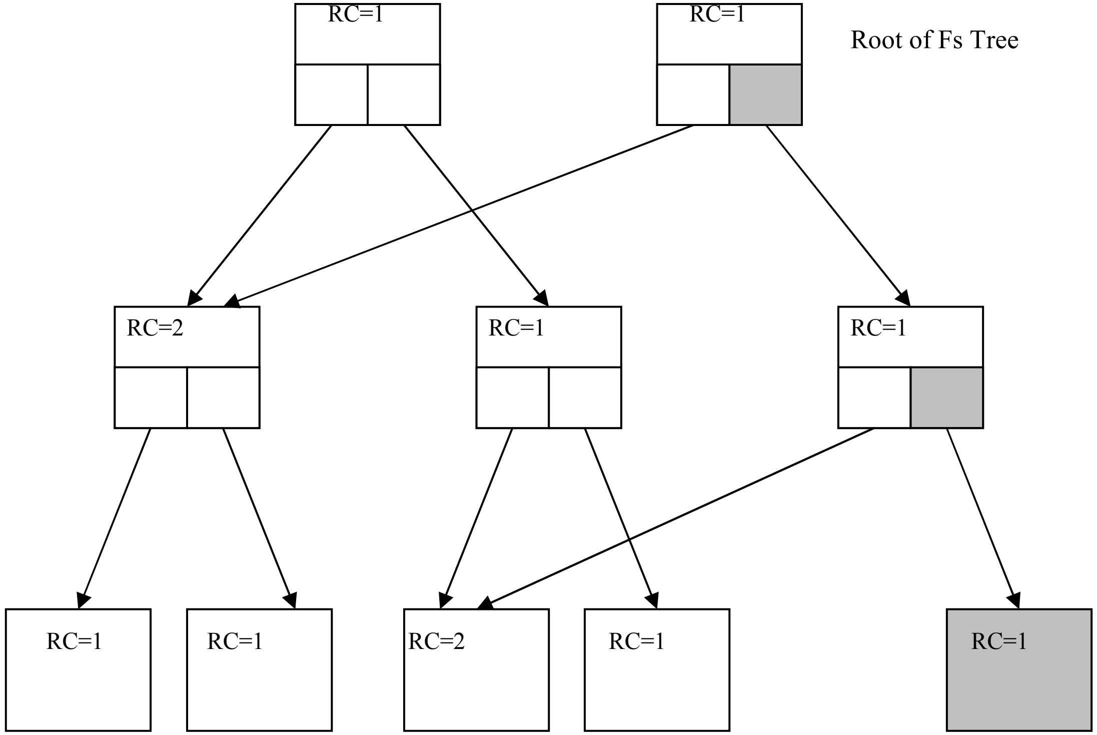

Application
File
Extent 1
Extent 2
Extent 3
…
Extent N
Change the relative Checksums
Csum tree
Log the changed csum data of this file
Log tree
Extent1 Csum
Extent2 Csum
Extent3 Csum
ExtentN Csum
Write to disk
Disk
Checksum of the file's extent
Checksum of the file's extent that be changed
The extent that be changed

Implementation of the features

- Snapshot
  - Use the reference counter of the extent
  - Create a new file tree and copy the root of the original fs/file tree
  - Insert directory item and directory name index into the parent fs/file tree

Implementation of the features

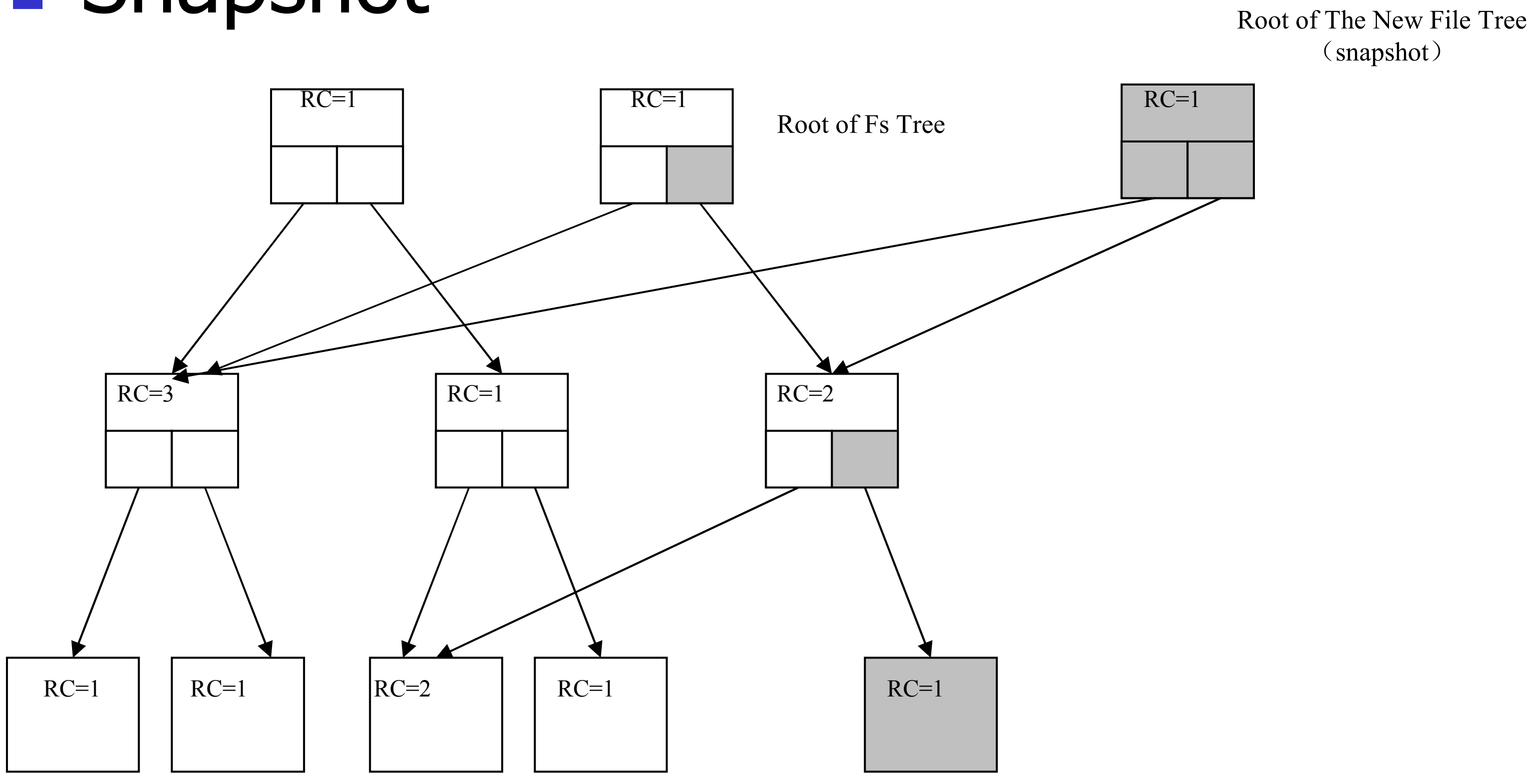
- Snapshot



Step1 before creating snapshot

Implementation of the features

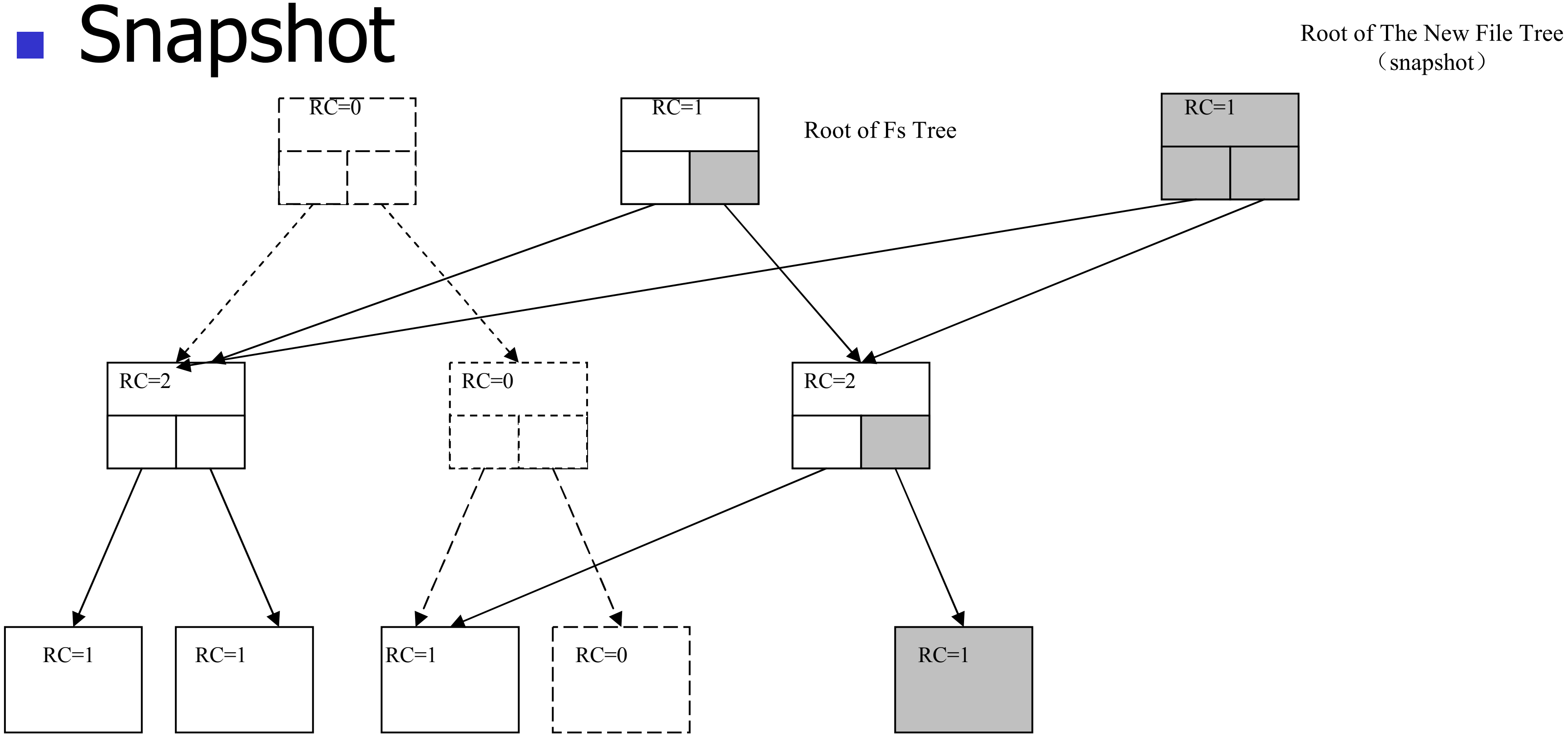
- Snapshot



Step2 after creating snapshot

Implementation of the features

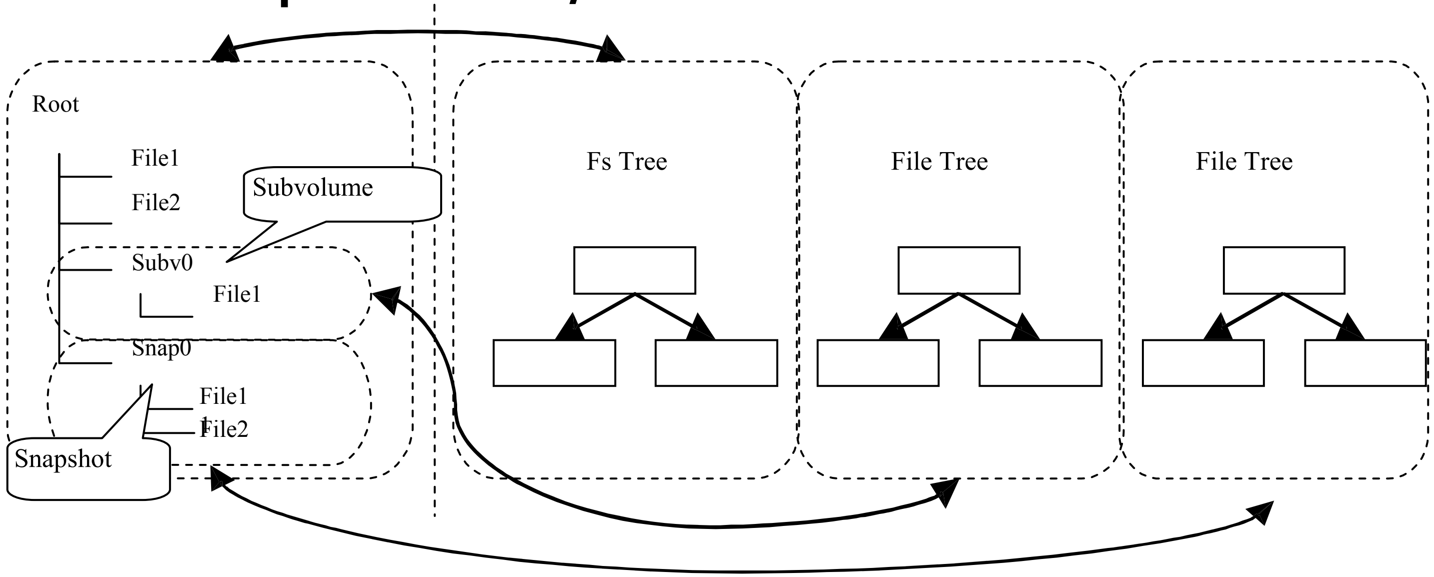
- Snapshot



Step3 After committing the transaction

Implementation of the features

- Subvolume
  - Insert a new file tree into the root tree
  - Insert directory item and directory name index into the parent fs/file tree



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What did we do for Btrfs?

- Introduce LZO compression
- Inode ID allocator
- Improve Chunk allocator
  - Utilize the device space better
- Improve tree log
  - By introduce the sub transaction id
- Delayed metadata update
- …

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How do I use Btrfs?

Reference

- 新一代 Linux 文件系统 btrfs 简介(刘明)
  http://www.ibm.com/developerworks/cn/linux/l-cn-btrfs/
- Btrfs Wiki
  http://btrfs.wiki.kernel.org/
- Btrfs Mail List
  linux-btrfs@vger.kernel.org

Reference

- Sourecode(Git)
  - http://git.kernel.org/?p=linux/kernel/git/mason/btrfs-progs-unstable.git
  - http://git.kernel.org/?p=linux/kernel/git/mason/btrfs-unstable.git

Thanks!

Q/A