- [x] 1. Last time
- [x] 2. Finish directories
- [x] 3. Performance
- [ ] 4. Crash recovery
  - intro
  - ad hoc
  - copy on write
  - journaling

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2. Finish directories

Example: /a/foo.c
/b/c/essay.txt

inode #7 (by assumption)

We can give a file another name; for example
/a/hello.txt

This is because the file itself does not know its own name. Looking only at the file, the "name" is just a i-node number.

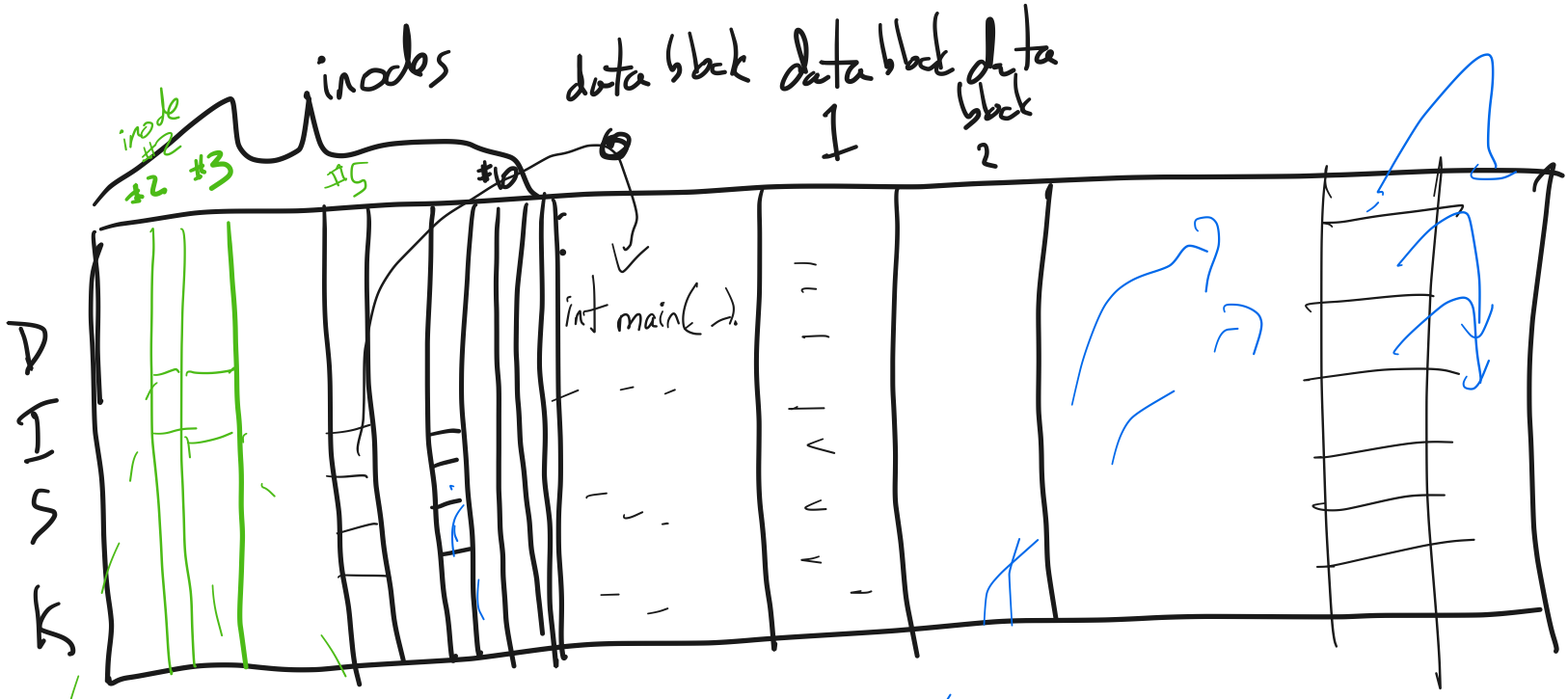
Human-usable names, such as /a/foo.c
are in directory entries, for example:

come from directory

<a, 3>
<b, 4>

dirent ← readdir()
↳ lab2 d_name
d_no

which means "let us all call inode 3 by the segment "/a", and similarly for inode 4 and "/b".



<a, 3>
<b, 4>
<mylink, 10>

<foo.c, 5>
<hello.txt, 7>

$ ln /b/c/essay.txt /a/hello.txt

"link"

syscall: "unlink();"

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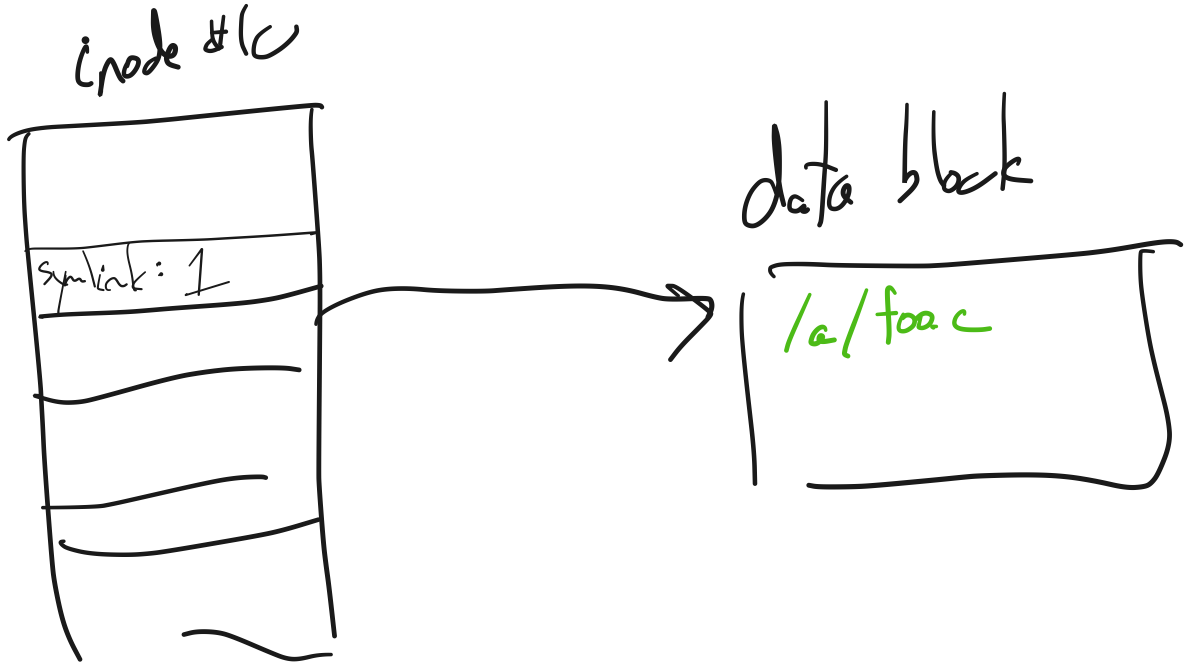
soft links vs. hard links

$ ln -s /a/foo.c /mylink

creates a new inode (#10)



symlink bit set 1.

/a/b/c

dst name

$ ln ____ ____

mount points

$ cat /a/foo.c

---

3. Performance

case study: FFS (1984)

problems w/ the original:

- blocks too small (512)
- inode array was at beginning of disk
- free blocks were stored in a linked list on the disk
- poor clustering of related objects
  - consecutive file blocks
  - inodes relative to disk blocks
  - [illegible] directory

inodes for a given directory

result:

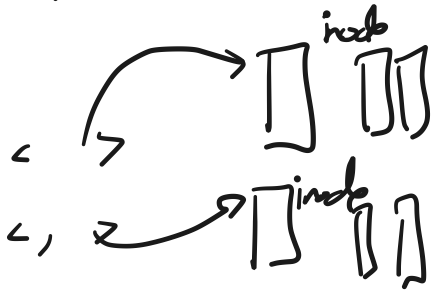
ls

grep <path> *.c

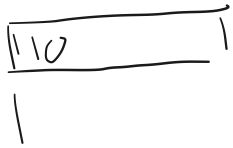
} ⇒ slow

Improvements?

- Make data blocks / inodes close to each other



- Cluster files in the same directory
- Make data blocks bigger (4KB, 8KB, 16KB)
- Free blocks: store separately (bitmap)



$\frac{1\text{ block}}{1\text{ bit}}$ × 500 GB disk / 4KB blocks = 12

$2^{39} / 2^{12} = 2^{27} \approx$ 1 disk: 128,000,000 bits

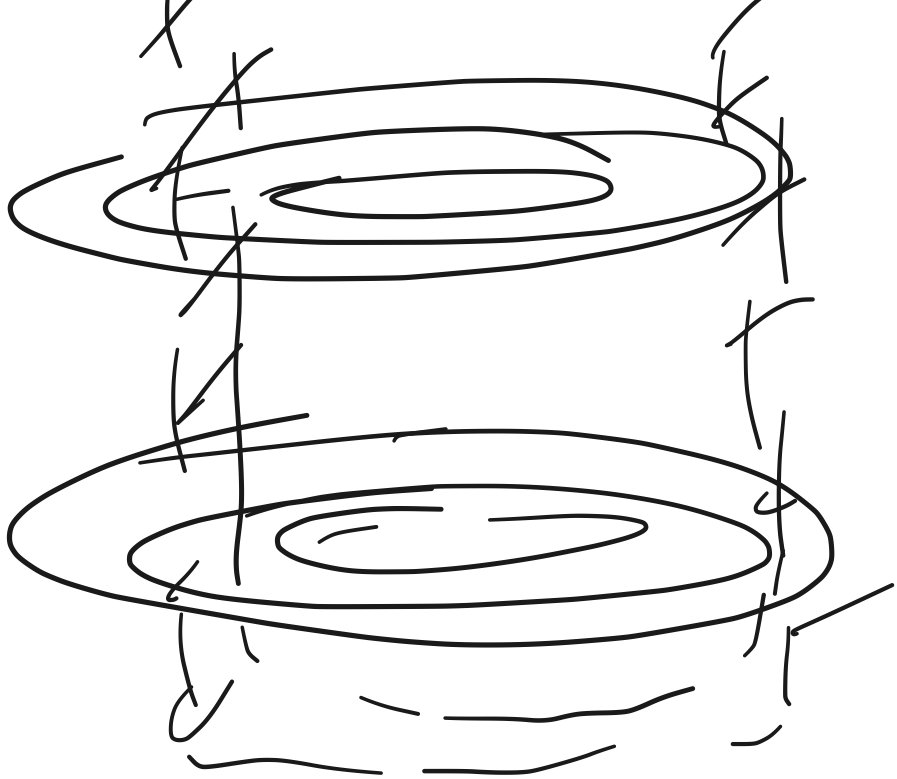
$\approx$ 16 MB ⇐ store in memory

2^{27} bits $\times \frac{1 \text{ byte}}{2^3 \text{ bits}} = 2^{24}$ bytes

$= 16$ MB

⇒ reserve space (lie to the user abt free space)

- symbolic links
- atomic "rename" ($ mv abc.txt def.txt)
- cylinder groups (for clustering)



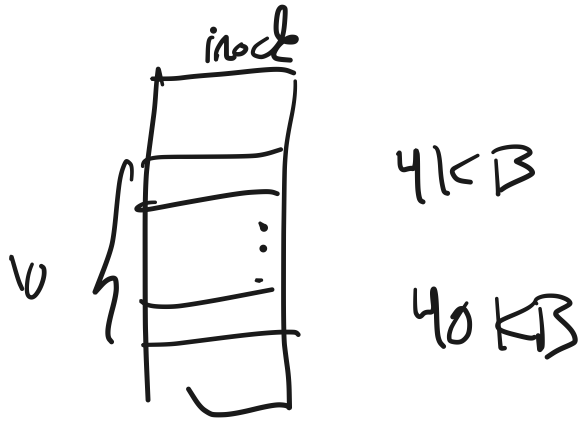
[superblock | bookkeeping | inodes | bitmap | data blocks (512 bytes each)]

attempt: put inodes + their data blocks in the same cyl. grp.

attempt: put inodes of ~~the~~ files in the same dir. in the same cyl. group.

new directory: choose a cyl. group w/ higher than avg. # of free inodes.

as a file grows, after it crosses 48 KB, spill to next cyl. group, and do likewise for every 1 MB thereafter.



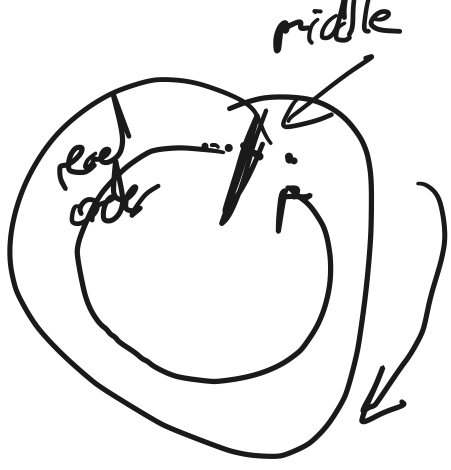
total perf:

20-40% of disk B/w for large files

10-20x improvement on the predecessor.

Other things they did:

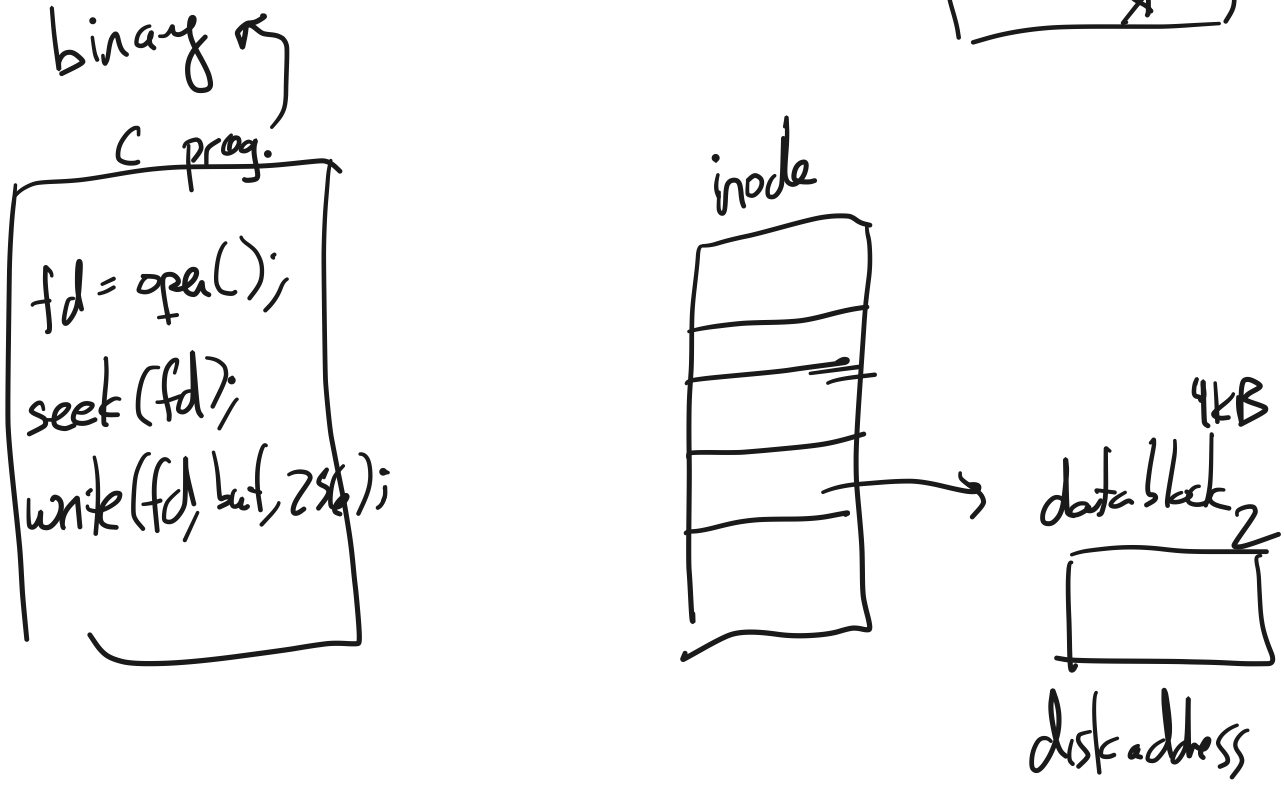
- buffer cache
- read entire track



4. Crash recovery

- intro
- ad-hoc → fsck
- copy-on-write
- journaling

Ex.



- add to inode
- write data to the block

- update the bitmap

What happens if there is a crash anywhere in this list of operations?

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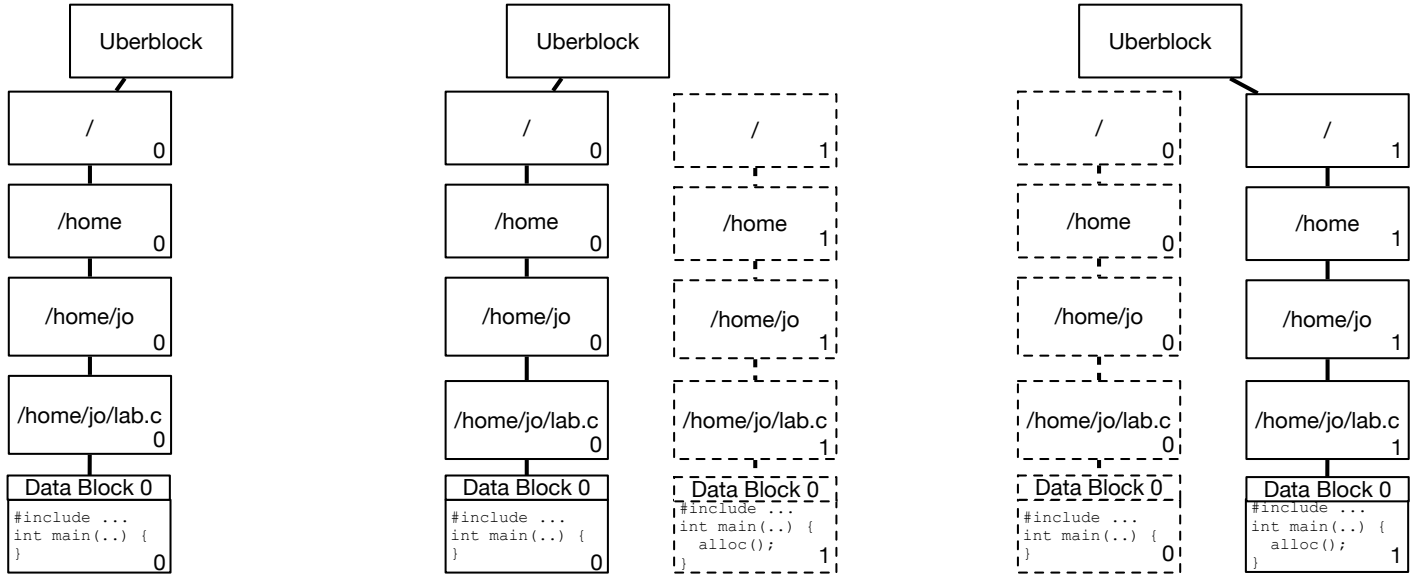
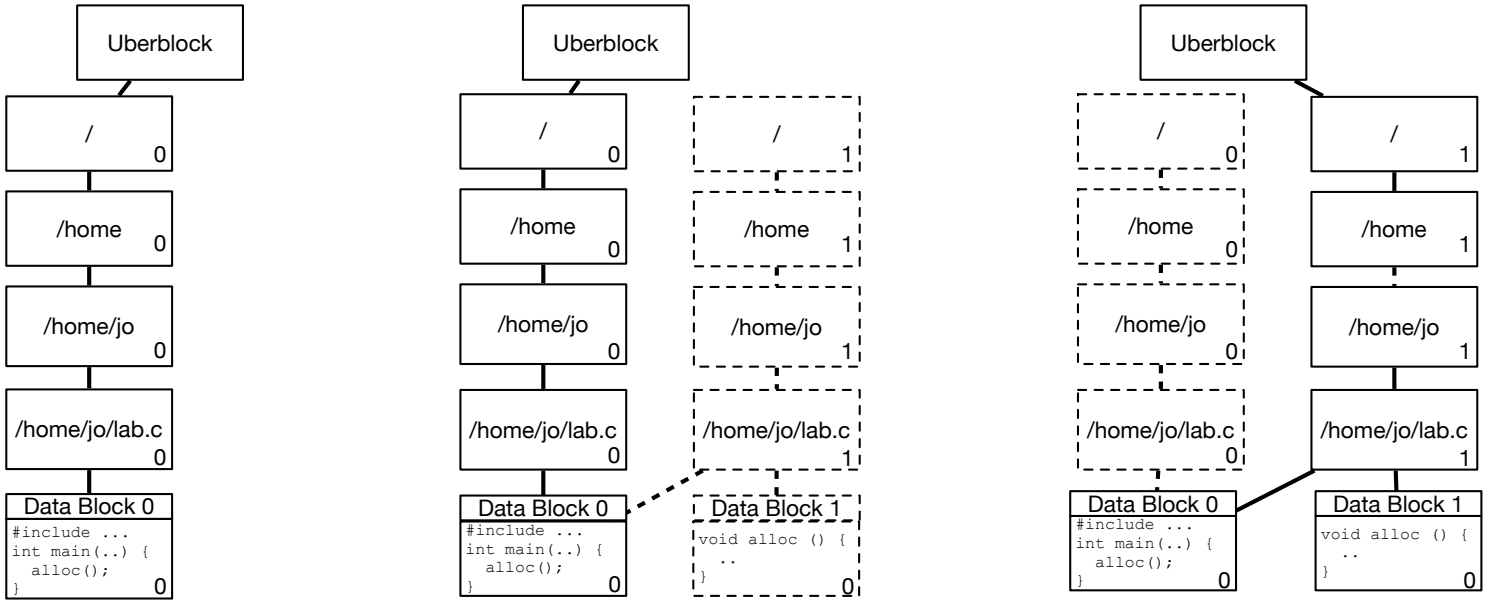


(a) Initial State

(b) System allocates and creates new versions of all modified blocks.

(c) System updates Uberblock to point to new version of blocks.

Figure 1: Copy-on-write filesystem: modifying a data block

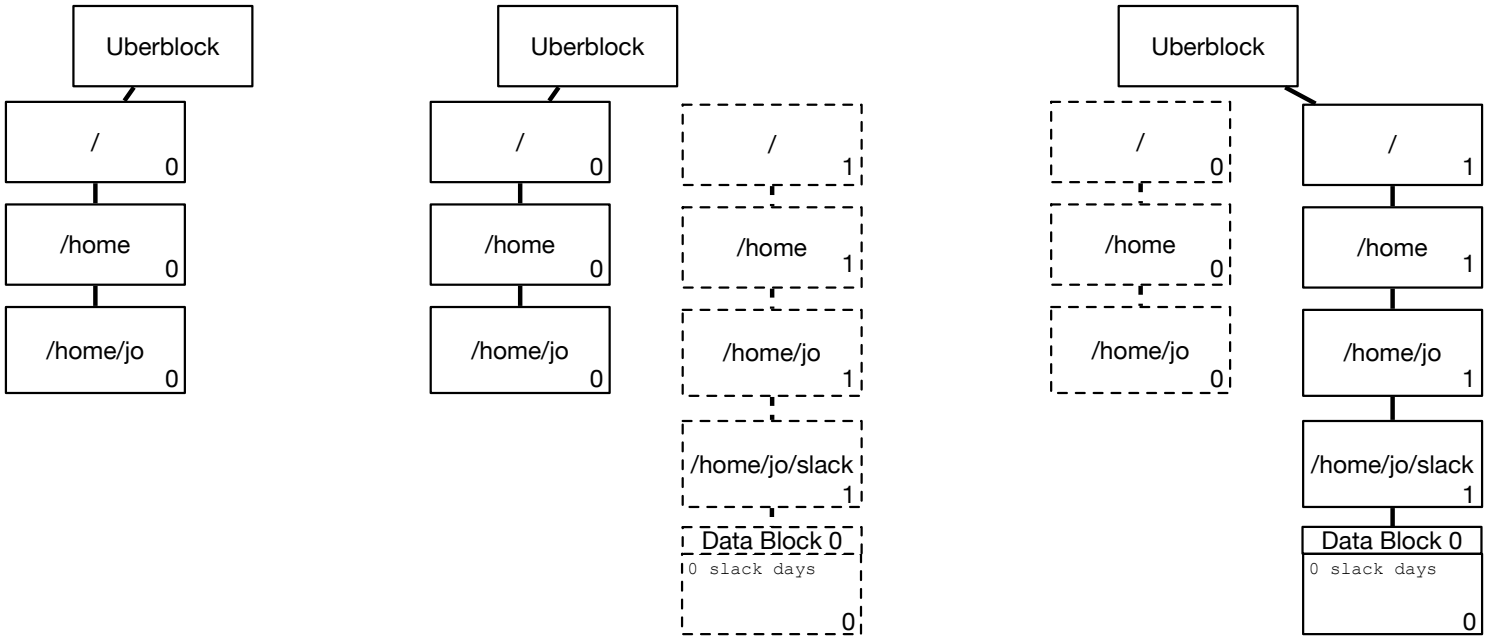


(a) Initial State

(b) System allocates and creates new versions of all modified blocks.

(c) System updates Uberblock to point to new version of blocks.

Figure 2: Copy-on-write filesystem: adding a data block



(a) Initial State

(b) System allocates and creates new versions of all modified blocks.

(c) System updates Uberblock to point to new version of blocks.

Figure 3: Copy-on-write filesystem: creating a file

Figure 4: Redo logging in a filesystem