YAFFS2 Support

VIAFORENSICS

Oct 2012

Android YAFFS2

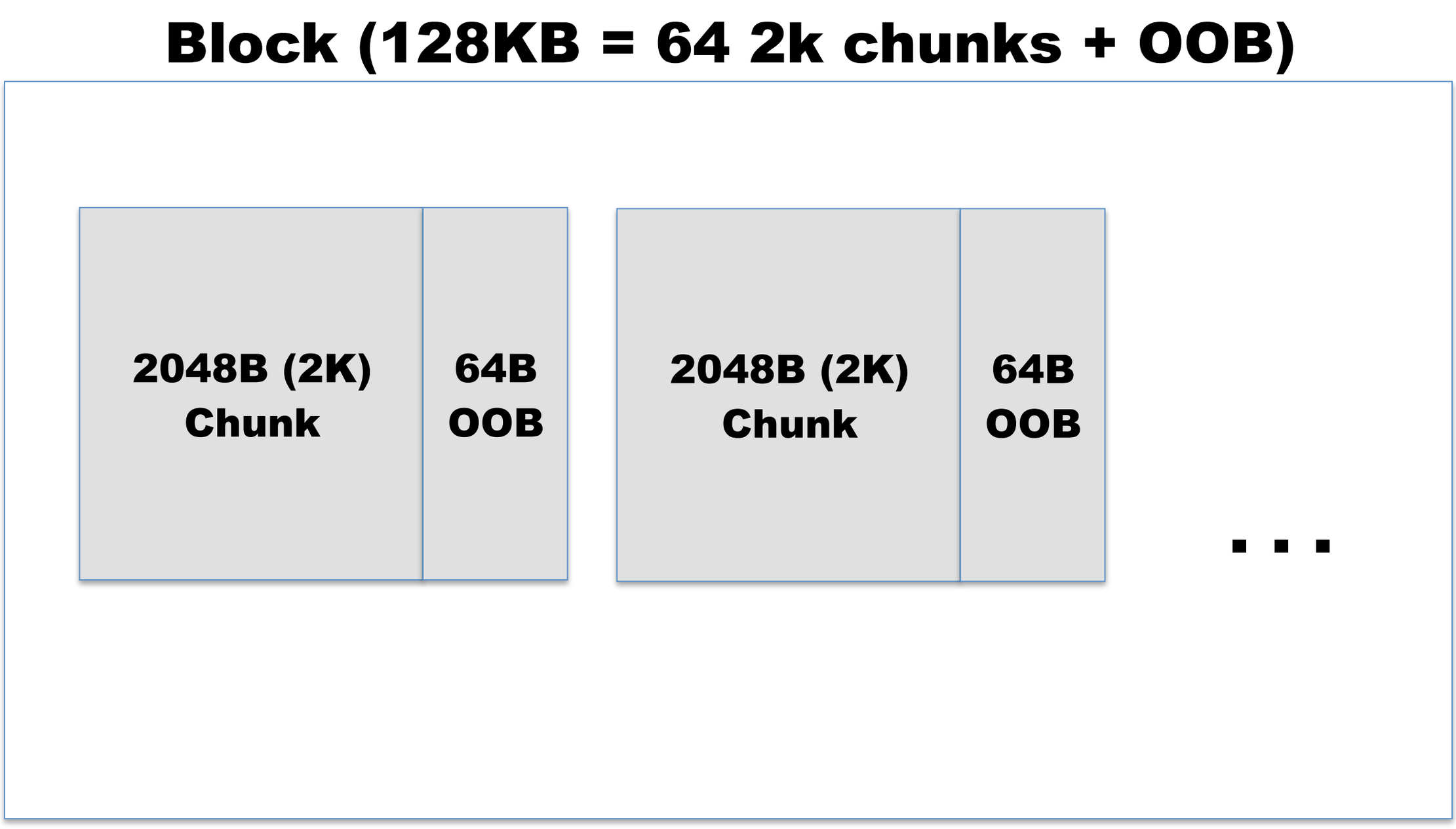
- Yet Another Flash File System 2
- Open source
- Have to compile tools/kernel module yourself (some optional support in newer kernels)
- Provides
  - Log-structured file system (think versioning)
  - Wear leveling
  - Much faster and YAFFS and JFFS, uses less RAM
  - Supports many flash geometries
  - Built in error correction (important to use nandread/nandwrite tools!)

YAFFS2 Data Structures

- Data stored in YAFFS2 are referred to as Objects
  - Files
  - Directories
  - Symbolic and hard links

- Chunk stores either an Object or an yaffs_ObjectHeader
  - Metadata about the Object
    - Object type, the parent object, a checksum of the name to speed up searching, the object name, permissions and ownership, MAC information and the size of the object if it is a file
  - All objects are identified by a unique objectId (i.e. inodes)

YAFFS2 – Block/Chunk/OOB diagram



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Ever tried to mount YAFFS2 on Linux?

```
$ sudo apt-get install mtd-utils
Compile YAFFS2 from source

$ sudo modprobe mtd
$ sudo modprobe mtdblock
$ sudo modprobe nandsim first_id_byte=0x20 second_id_byte=0xa2
third_id_byte=0x00 fourth_id_byte=0x15

$ cat /proc/mtd
dev:    size   erasesize  name
mtd0: 04000000 00020000 "NAND simulator partition 0"

$ sudo insmod ~/yaffs2/yaffs2.ko

(optional) $ sudo nandwrite -autoplace -oob /dev/mtd0 yaffs2.nanddump

$ sudo mount -t yaffs2 /dev/mtdblock0 ~/mnt/yaffs2/
```

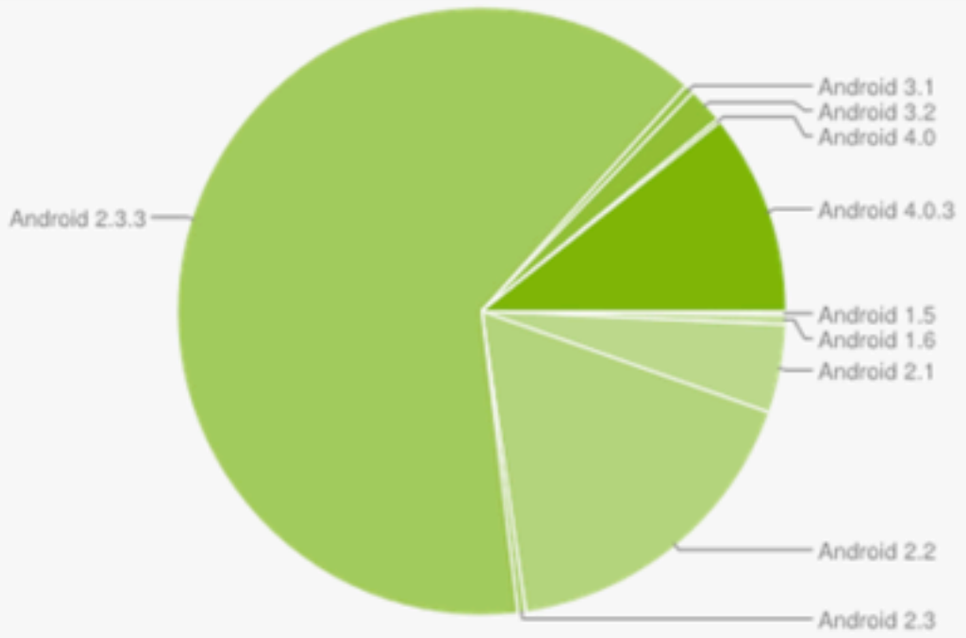
Mount YAFFS2 results (or order of likeliness)

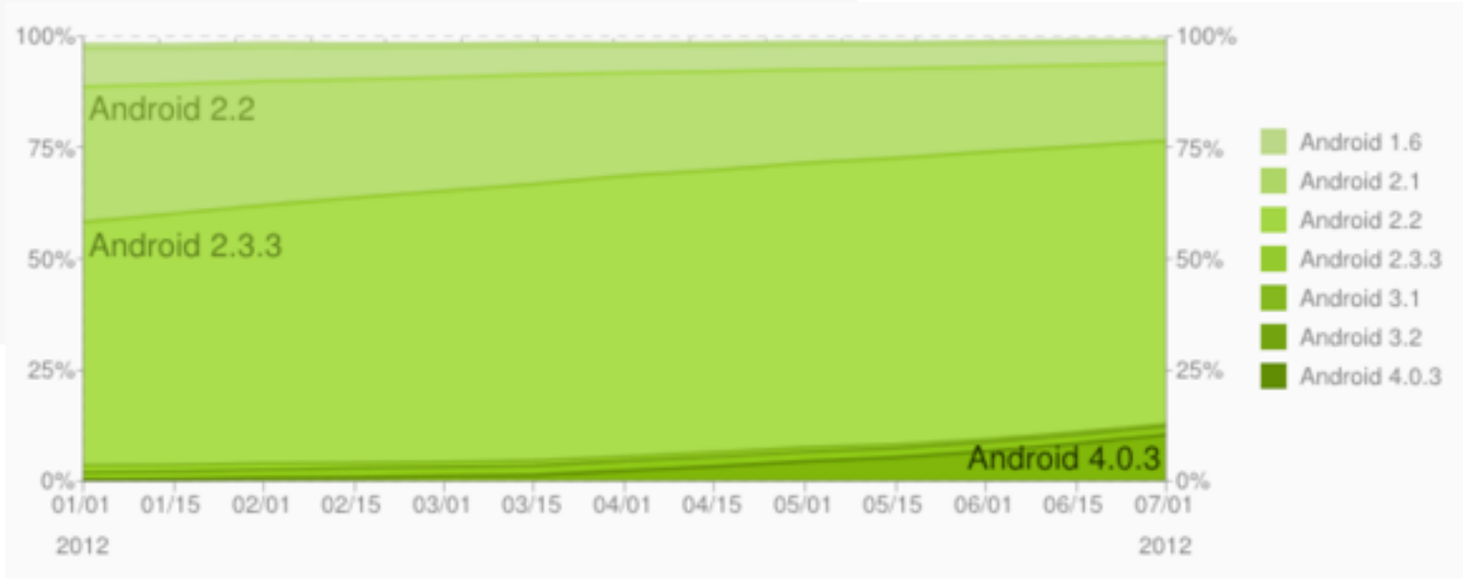
```
Fail
---------
mount: wrong fs type, bad option, bad superblock on /dev/mtdblock0,
missing codepage or helper program, or other error
In some cases useful info is found in syslog - try
dmesg | tail or so

No data
---------
$ ls -la ~/mnt/yaffs2/
total 8
drwxr-xr-x 1 root  root  2048 2011-02-03 11:37 .
drwxr-xr-x 3 ahoog ahoog 4096 2011-02-03 07:21 ..
drwx------ 1 root  root  2048 2011-02-03 11:37 lost+found


Actually worked (rare)
---------
<Imagine listing of files here>
```

Why Fail?

Version	Codename	API Level	Distribution
1.5	Cupcake	3	0.2%
1.6	Donut	4	0.5%
2.1	Eclair	7	4.7%
2.2	Froyo	8	17.3%
2.3 - 2.3.2	Gingerbread	9	0.4%
2.3.3 - 2.3.7		10	63.6%
3.1	Honeycomb	12	0.5%
3.2		13	1.9%
4.0 - 4.0.2	Ice Cream Sandwich	14	0.2%
4.0.3 - 4.0.4		15	10.7%

Data collected during a 14-day period ending on July 2, 2012





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Header Objects

Yaffs2_ObjectHeader
struct {
....
}

Parent ⟶
Name ⟶

```
struct yaffs_obj_hdr {
        enum yaffs_obj_type type;
        int parent_obj_id;
        u16 sum_no_longer_used; /* checksum of name. No longer used */
        YCHAR name[YAFFS_MAX_NAME_LENGTH + 1];
        u32 yst_mode;
        u32 yst_uid;
        u32 yst_gid;
        u32 yst_atime;
        u32 yst_mtime;
        u32 yst_ctime;
        int file_size; (object type: file)
        int equiv_id; (object type: symbolic)
        YCHAR alias[YAFFS_MAX_ALIAS_LENGTH + 1];
        u32 yst_rdev;
        u32 win_ctime[2];
        u32 win_atime[2];
        u32 win_mtime[2];
        u32 inband_shadowed_obj_id;
        u32 inband_is_shrink;
        u32 reserved[2];
        int shadows_obj;
        u32 is shrink;};
```

⟵ Obj Type

⟵ File Times

A few highlights

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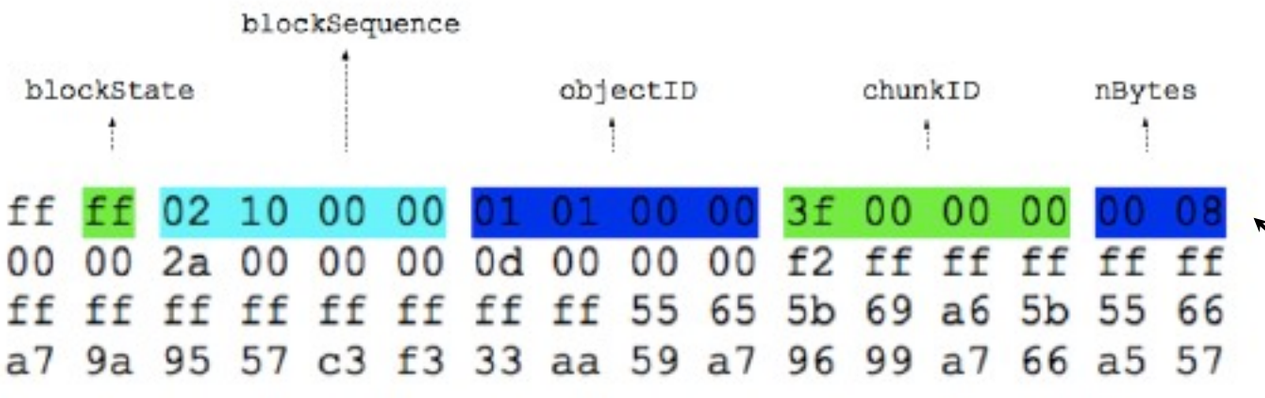
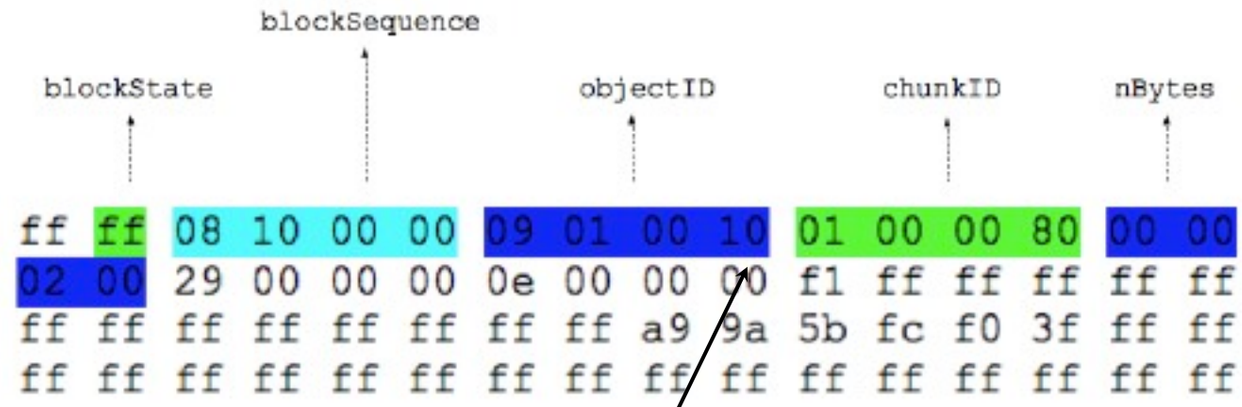
Out Of Band / Spare Area



OOB Data Chunk

0x800 file size means page is fully used.

OOB File Header



Object Type

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Verification through OOB

Field	Size for 1024 bytes chunks	Size for 2048 bytes chunks
blockState	1 byte	1 byte
chunkID	4 bytes	4 bytes
objectID	4 bytes	4 bytes
nBytes	2 bytes	2 bytes
blockSequence	4 bytes	4 bytes
tagsEcc	3 bytes	3 bytes
ecc	12 bytes	24 bytes

- 0x00: Unknown object type
- 0x01: file
- 0x02: symbolic link
- 0x03: directory
- 0x04: hard link
- 0x05: special

The chunk is identified as object header when it meets the requirements:

1. The size of the chunk must be larger than 512 bytes.
2. Bytes 0-3 should be equal to one of the object type values
3. Bytes 8-9 should be equal to 0xFFFF (not used)
4. All bytes from offset 512 onward should be equal to 0xFF

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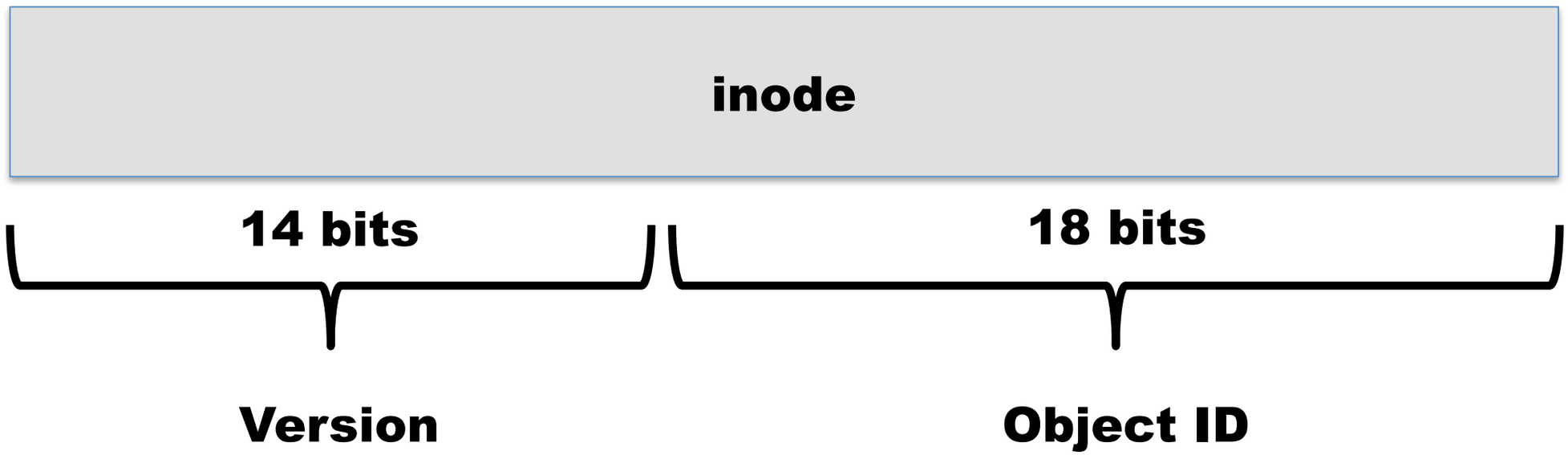
YAFFS2 – TSK inode Mapping



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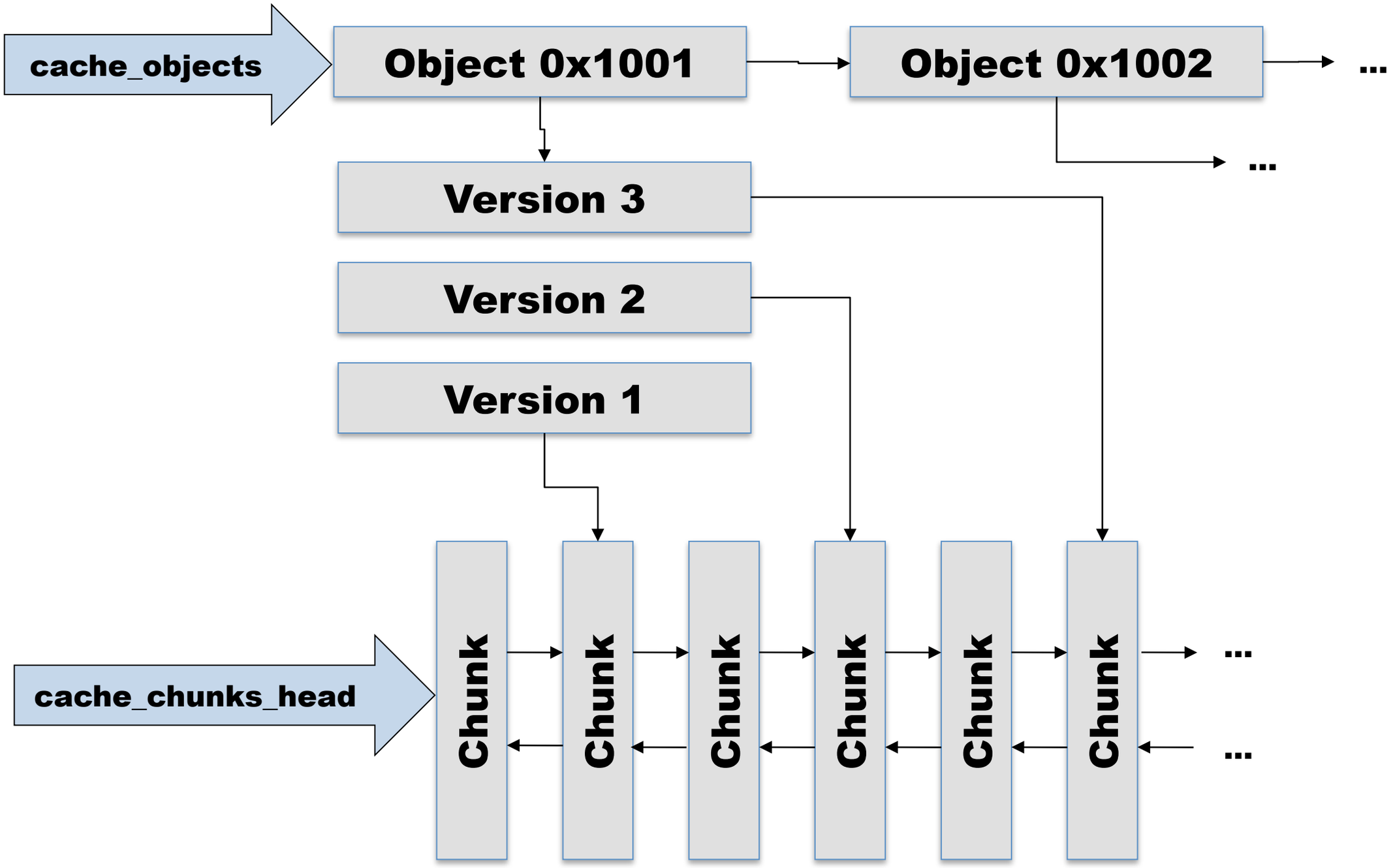
YAFFS2 – TSK Cache scanned at tsk_open



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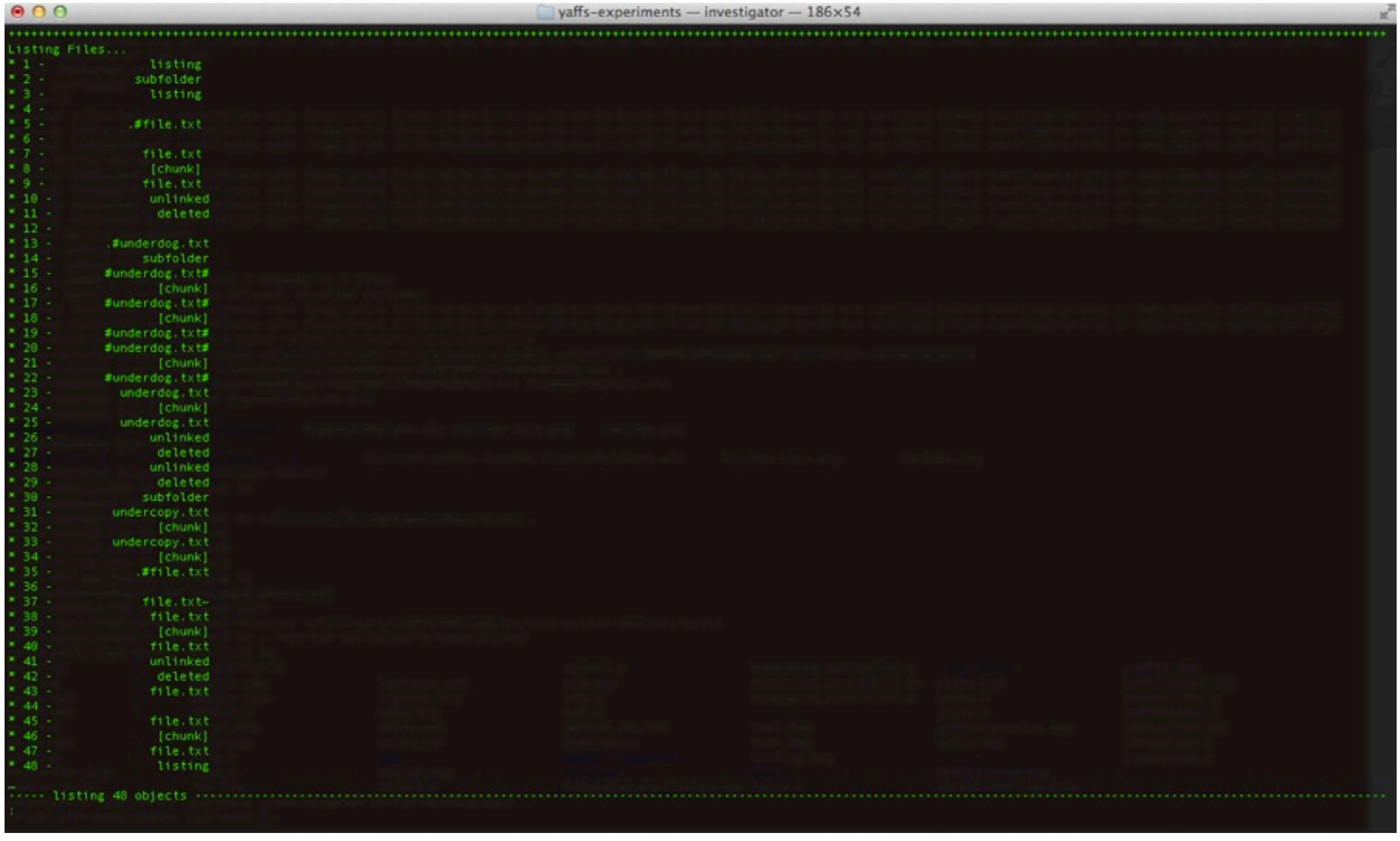
Looking at a Simple FS



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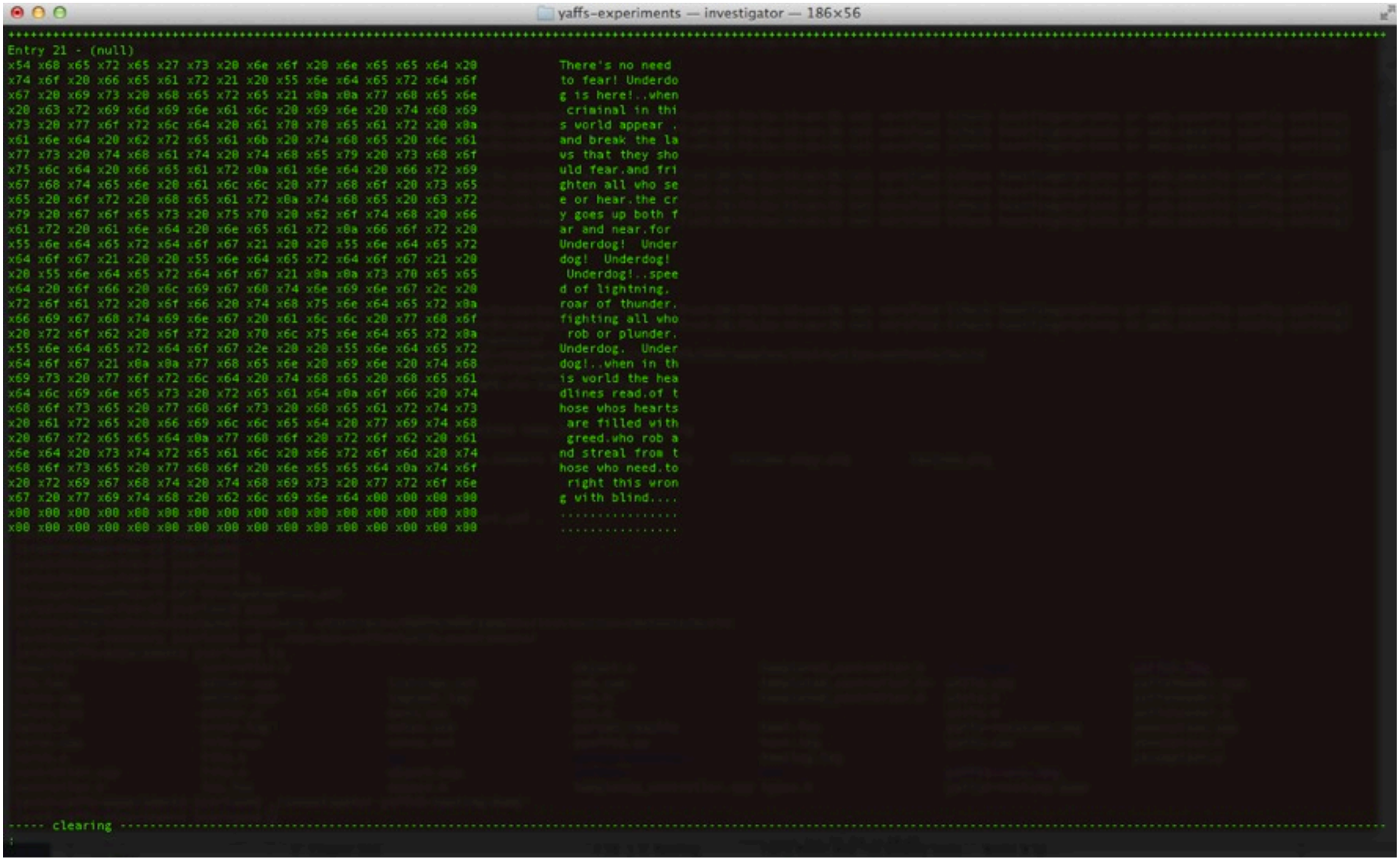
5 Entries Later...
We have Version 3



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Objects & Chunks (with ownership)

yaffs-experiments — investigator — 186×54

```
Listing Files...
* 1 -             listing
* 2 -           subfolder
* 3 -             listing
* 4 -
* 5 -          .#file.txt
* 6 -
* 7 -            file.txt
* 8 -             [chunk]      file.txt
* 9 -            file.txt
* 10 -            unlinked
* 11 -             deleted
* 12 -
* 13 -       .#underdog.txt
* 14 -            subfolder
* 15 -       #underdog.txt#
* 16 -              [chunk]     #underdog.txt#
* 17 -       #underdog.txt#
* 18 -              [chunk]     #underdog.txt#
* 19 -       #underdog.txt#
* 20 -       #underdog.txt#
* 21 -              [chunk]     #underdog.txt#
* 22 -       #underdog.txt#
* 23 -         underdog.txt
* 24 -              [chunk]     underdog.txt
* 25 -         underdog.txt
* 26 -             unlinked
* 27 -              deleted
* 28 -             unlinked
* 29 -              deleted
* 30 -            subfolder
* 31 -       undercopy.txt
* 32 -              [chunk]     undercopy.txt
* 33 -       undercopy.txt
* 34 -              [chunk]     #underdog.txt#
* 35 -          .#file.txt
* 36 -
* 37 -            file.txt~
* 38 -             file.txt
* 39 -             [chunk]     file.txt
* 40 -            file.txt
* 41 -            unlinked
* 42 -             deleted
* 43 -            file.txt
* 44 -
* 45 -            file.txt
* 46 -             [chunk]     file.txt
* 47 -            file.txt
* 48 -             listing

----- listing 48 objects -----
:
```

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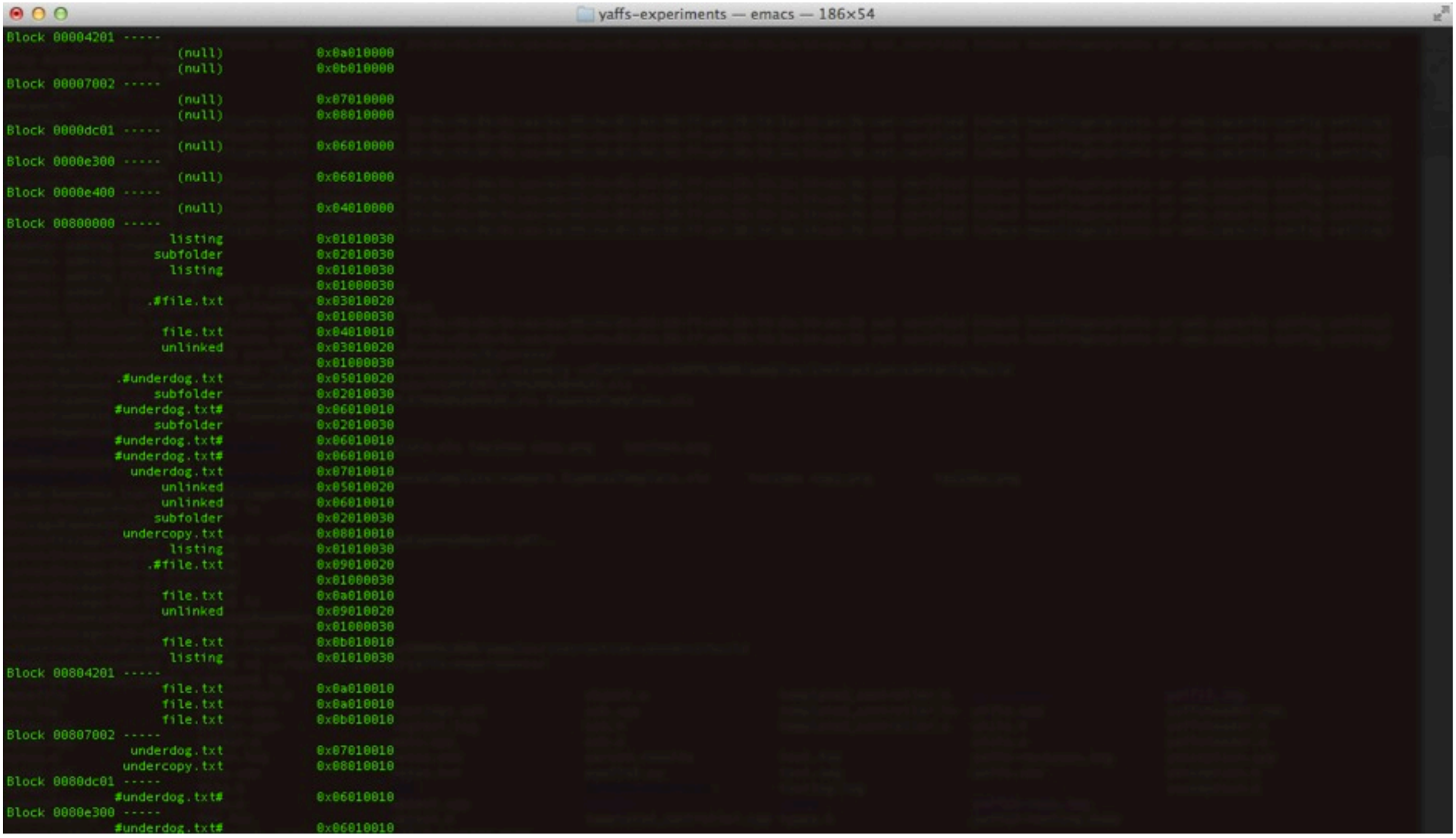
Reordering FS by Blocks



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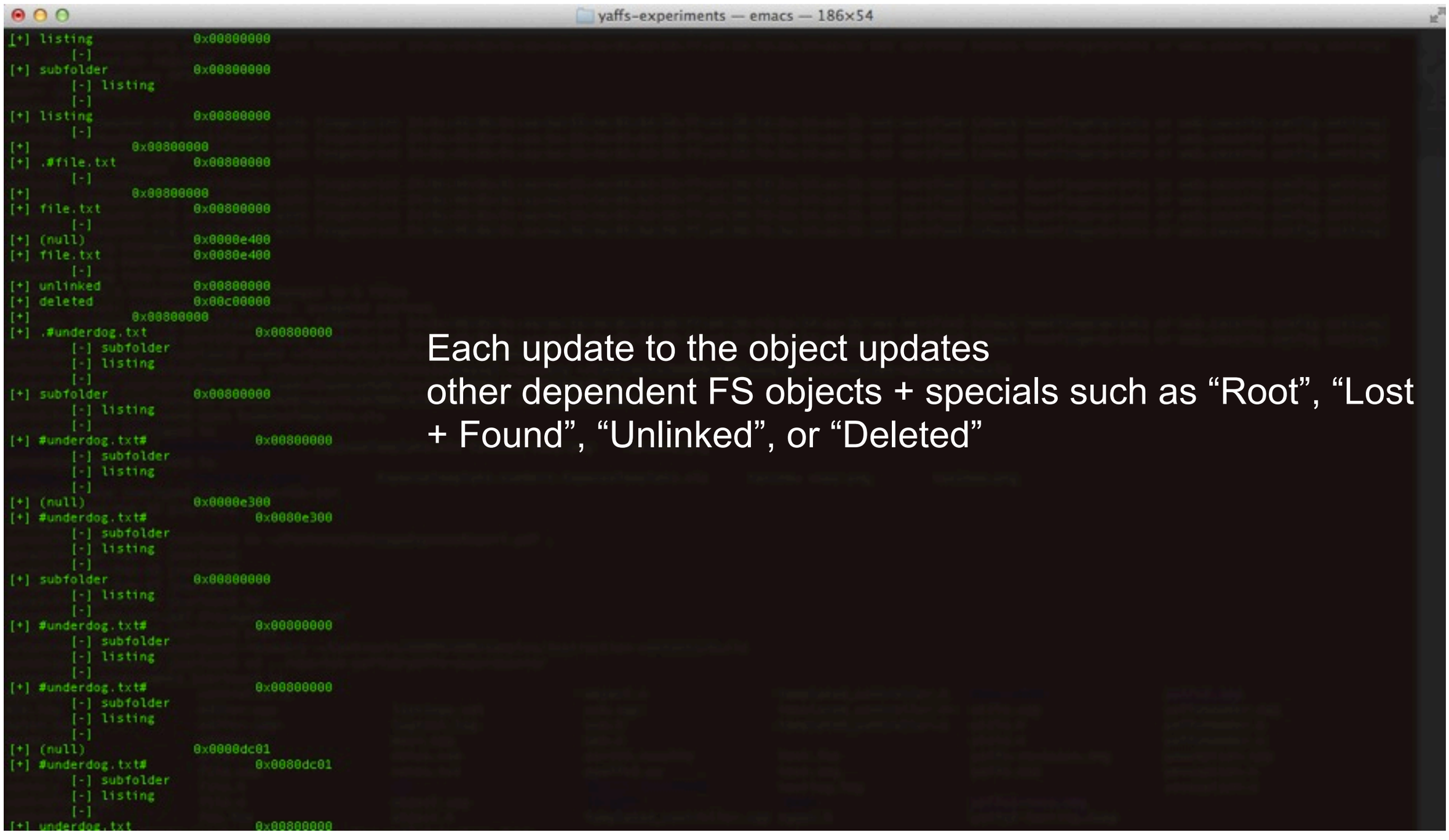
Mapping Actions to a Timeline



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YAFFS2 in hex

```
0002940: 0100 0000 1a01 0000 ffff 6261 7474 6572  ..........batter
0002950: 7973 7461 7473 2e62 696e 0000 0000 0000  ystats.bin......
0002960: 0000 0000 0000 0000 0000 0000 0000 0000  ................
0002970: 0000 0000 0000 0000 0000 0000 0000 0000  ................
0002980: 0000 0000 0000 0000 0000 0000 0000 0000  ................
0002990: 0000 0000 0000 0000 0000 0000 0000 0000  ................
00029a0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
00029b0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
00029c0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
00029d0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
00029e0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
00029f0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
0002a00: 0000 0000 0000 0000 0000 0000 0000 0000  ................
0002a10: 0000 0000 0000 0000 0000 0000 0000 0000  ................
0002a20: 0000 0000 0000 0000 0000 0000 0000 0000  ................
0002a30: 0000 0000 0000 0000 0000 0000 0000 0000  ................
0002a40: 0000 0000 0000 0000 0000 ffff 8081 0000  ................
0002a50: e803 0000 e803 0000 6899 b34c 6899 b34c  ........h..Lh..L
0002a60: 6899 b34c 80ab 0000 ffff ffff ffff ffff  h..L............
```

https://viaforensics.com

fsstat output

```
$ fsstat -f yaffs2 yaffs2-nexus-one-postdeletion.nanddump

FILE SYSTEM INFORMATION
--------------------------------------------
File System Type: YAFFS2
Page Size: 2048
Spare Size: 64

METADATA INFORMATION
--------------------------------------------
Number of Allocated Objects: 961
Object Id Range: 1 - 1341
Number of Total Object Versions: 7365
Object Version Range: 4097 - 4930
```

YAFFS2 images: https://viaforensics.com/products/tools/sleuth-kit-yaffs2/

fls output

```
$ fls -p -r -f yaffs2 yaffs2-nexus-one-postdeletion.nanddump (7364 results)
d/d 262146:     lost+found:2,1
d/d 262405:     dontpanic:261,1
d/d 4980998:    misc:262,19
r/r 2359555:    misc:262,19/AK8973Prms.txt:259,9
d/d 262407:     misc:262,19/bluetoothd:263,1
d/d 262408:     misc:262,19/keystore:264,1
d/d 262409:     misc:262,19/vpn:265,1
d/d 262410:     misc:262,19/vpn:265,1/profiles:266,1
d/d 524555:     misc:262,19/wifi:267,2
d/d 524564:     misc:262,19/wifi:267,2/sockets:276,2
r/- 4719206:    misc:262,19/wifi:267,2/sockets:276,2/wpa_ctrl_97-0:614,18
r/- 1311349:    misc:262,19/wifi:267,2/sockets:276,2/wpa_ctrl_97-1:629,5
d/d 262420:     misc:262,19/wifi:267,2/sockets:276,1
r/r 3670612:    misc:262,19/wifi:267,2/wpa_supplicant.conf:596,14
r/r 3408468:    misc:262,19/wifi:267,2/wpa_supplicant.conf:596,13
d/d 262411:     misc:262,19/wifi:267,1
d/d 524565:     misc:262,19/dhcp:277,2
r/r 786976:     misc:262,19/dhcp:277,2/dhcpcd-eth0.pid:544,3
r/r 1311275:    misc:262,19/dhcp:277,2/dhcpcd-eth0.lease:555,5
d/d 262421:     misc:262,19/dhcp:277,1
r/r 524566:     misc:262,19/rild_ril.prefer.network.select-type:278,2
r/r 262422:     misc:262,19/rild_ril.prefer.network.select-type:278,1
r/r 524567:     misc:262,19/rild_ril.band.select-mode:279,2
```

Two versions of wpa_supplicant file

```
$ icat -f yaffs2 yaffs2-nexus-one-postdeletion.nanddump 3408468

##### wpa_supplicant configuration file template #####
update_config=1
ctrl_interface=eth0
eapol_version=1
ap_scan=1
fast_reauth=1
```

```
$ icat -f yaffs2 yaffs2-nexus-one-postdeletion.nanddump 3670612

ctrl_interface=eth0
update_config=1

network={
     ssid="Droid"
     psk="mountyaffs2"
}
```

YAFFS2 in hex

```
$ grep 596\, ~/fls.txt

r/r 3670612:    misc:262,19/wifi:267,2/wpa_supplicant.conf:596,14
r/r 3408468:    misc:262,19/wifi:267,2/wpa_supplicant.conf:596,13

r/r 2359892:    data:270,10/com.google.android.server.checkin:320,3/
databases:436,266/checkin.db-journal:596,9

r/r 262740:     data:270,10/com.google.android.providers.gmail:329,3/
databases:624,40/mailstore.yaffs2.drjohn@gmail.com.db-journal:596,1

r/r 3146324:    <deleted>/deleted:596,12
r/r 2884180:    <deleted>/deleted:596,11
r/r 2622036:    <deleted>/deleted:596,10
r/r 2097748:    <deleted>/deleted:596,8
r/r 1835604:    <deleted>/deleted:596,7
r/r 1573460:    <deleted>/deleted:596,6
r/r 1311316:    <deleted>/deleted:596,5
r/r 1049172:    <deleted>/deleted:596,4
r/r 787028:     <deleted>/deleted:596,3
r/r 524884:     <deleted>/deleted:596,2
```

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Looking at SQLite journal file

```
$ icat -f yaffs2 yaffs2-nexus-one-postdeletion.nanddump 262740 | xxd -a

0000000: d9d5 05f9 20a1 63d7 0000 0000 922f 78c3  .... .c....../x.
0000010: 0000 0030 0000 0200 0000 0400 0000 0000  ...0............
0000020: 0000 0000 0000 0000 0000 0000 0000 0000  ................
*
00001f0: 0000 0000 0000 0000 0000 0000 0000 0000  ................


Recall from fls:
r/r 262740:     data:270,10/com.google.android.providers.gmail:329,3/
databases:624,40/mailstore.yaffs2.drjohn@gmail.com.db-journal:596,1
```

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Santoku Linux

- Free and open bootable Linux distribution full of tools

- Project is a collaboration with other mobile security and forensic pros

- Mobile Forensics

- Mobile App Security Testing

- Mobile Malware Analysis

Check out the Alpha release at **https://santoku-linux.com**

Sources

- YAFFS2 Object Headers - Identifying and parsing YAFFS2 objects. Ivo Pooters, Pascal Arends and Steffen Moorress

- Reverse Engineering of the Android File System - YAFFS 2. Sven Schmitt, Michael Spreitzenbarth, Christian Zimmerman.

- How YAFFS Works. Charles Manning

- A. Hoog Android Forensics: Investigation, Analysis and Mobile Security for Google Android 1st ed. Syngress Press, 2011.

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