

# REPORT

## OS Lab3 Filesystem



과 목 명 : 운영체제

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## Goal

- 램디스크를 파일시스템에 올리는 과정을 이해한다
- Ext2 파일 시스템의 내부 구조를 파악한다.
- 원하는 디렉토리와 파일을 찾아 해당 파일에 할당 받은 블록을 찾을 수 있다.

## Analysis results and snapshots

먼저 깃허브에서 lab3를 clone 해오고 root권한으로 변경해준 다음 make로 ramdisk.ko 모듈파일을 만들어준다.

```
File Edit View Search Terminal Help
oslab@oslab:~$ ls
2022_DKU_OS  Documents  examples.desktop  Pictures  Templates
Desktop      Downloads  Music             Public    Videos
oslab@oslab:~$ cd 2022_DKU_OS
oslab@oslab:~/2022_DKU_OS$ ls
lab1_sched  lab2_sync  lab3_filesystem  README.md
oslab@oslab:~/2022_DKU_OS$ cd lab3_filesystem
oslab@oslab:~/2022_DKU_OS/lab3_filesystem$ ls
append.c  create.sh  Makefile  os_ext2  ramdisk.c
oslab@oslab:~/2022_DKU_OS/lab3_filesystem$ sudo su
[sudo] password for oslab:
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# make
make -C /lib/modules/5.4.0-84-generic/build M=/home/oslab/2022_DKU_OS/lab3_filesystem modules
make[1]: Entering directory '/usr/src/linux-headers-5.4.0-84-generic'
CC [M] /home/oslab/2022_DKU_OS/lab3_filesystem/ramdisk.o
Building modules, stage 2.
MODPOST 1 modules
CC [M] /home/oslab/2022_DKU_OS/lab3_filesystem/ramdisk.mod.o
LD [M] /home/oslab/2022_DKU_OS/lab3_filesystem/ramdisk.ko
make[1]: Leaving directory '/usr/src/linux-headers-5.4.0-84-generic'
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# ls
append.c  modules.order  ramdisk.c  ramdisk.mod.c
create.sh  Module.symvers  ramdisk.ko  ramdisk.mod.o
Makefile  os_ext2         ramdisk.mod  ramdisk.o
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem#
```

Insmod로 ramdisk.ko 모듈파일을 적재한다.

```
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# insmod ramdisk.ko
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# lsmod | grep ramdisk.ko
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# lsmod | grep ramdisk
ramdisk      16384  0
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem#
```

mnt 디렉토리를 만든 후 mkfs 명령어로 파일시스템을 포맷한 후 mnt에 mount 해준다.

```
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# mkdir mnt
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# ls
append.c  Makefile  modules.order  os_ext2  ramdisk.ko  ramdisk.mod.c  ramdisk.o
create.sh  mnt       Module.symvers  ramdisk.c  ramdisk.mod  ramdisk.mod.o
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# mkfs.ext2 /dev/ramdisk
mke2fs 1.44.1 (24-Mar-2018)
Creating filesystem with 131072 4k blocks and 32768 inodes
Filesystem UUID: 62f4e3f4-0879-477c-b611-994f7ddb890f
Superblock backups stored on blocks:
    32768, 98304

Allocating group tables: done
Writing inode tables: done
Writing superblocks and filesystem accounting information: done

root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem#
```

```
File Edit View Search Terminal Help
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# mount /dev/ramdisk ./mnt
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# df -h
Filesystem      Size  Used Avail Use% Mounted on
udev            970M   0  970M   0% /dev
tmpfs           199M  1.6M  198M   1% /run
/dev/sda1       9.8G  6.8G  2.6G  73% /
tmpfs           994M   0  994M   0% /dev/shm
tmpfs           5.0M  4.0K  5.0M   1% /run/lock
tmpfs           994M   0  994M   0% /sys/fs/cgroup
/dev/loop3      249M  249M   0 100% /snap/gnome-3-38-2004/99
/dev/loop2       66M   66M   0 100% /snap/gtk-common-themes/1515
/dev/loop0       2.5M  2.5M   0 100% /snap/gnome-calculator/884
/dev/loop1      242M  242M   0 100% /snap/gnome-3-38-2004/70
/dev/loop4      219M  219M   0 100% /snap/gnome-3-34-1804/72
/dev/loop5       45M   45M   0 100% /snap/snapd/15904
/dev/loop6       62M   62M   0 100% /snap/core20/1494
/dev/loop7      128K  128K   0 100% /snap/bare/5
/dev/loop8       62M   62M   0 100% /snap/core20/1434
/dev/loop9       2.5M  2.5M   0 100% /snap/gnome-system-monitor/163
/dev/loop10     640K  640K   0 100% /snap/gnome-logs/106
/dev/loop11      2.7M  2.7M   0 100% /snap/gnome-system-monitor/174
/dev/loop12      82M   82M   0 100% /snap/gtk-common-themes/1534
/dev/loop13       56M   56M   0 100% /snap/core18/2409
/dev/loop14       56M   56M   0 100% /snap/core18/2128
/dev/loop15     768K  768K   0 100% /snap/gnome-characters/741
/dev/loop16     640K  640K   0 100% /snap/gnome-logs/112
/dev/loop17     768K  768K   0 100% /snap/gnome-characters/726
/dev/loop18     219M  219M   0 100% /snap/gnome-3-34-1804/77
/dev/loop19      2.7M  2.7M   0 100% /snap/gnome-calculator/920
tmpfs           199M   16K  199M   1% /run/user/121
tmpfs           199M   40K  199M   1% /run/user/1000
tmpfs           199M   0  199M   0% /run/user/1000
tmpfs           199M   0  199M   0% /run/user/0
/dev/ramdisk    504M  396K  478M   1% /home/oslab/2022_DKU_OS/lab3_filesystem/mnt
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem#
```

./create.sh 실행으로 mnt에 0~9 디렉토리 생성

```
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# ls
append.c  Makefile  modules.order  os_ext2  ramdisk.ko  ramdisk.mod.c  ramdisk.o
create.sh  mnt       Module.symvers  ramdisk.c  ramdisk.mod  ramdisk.mod.o
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# ./create.sh
create files ...
done
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# ls mnt
0 1 2 3 4 5 6 7 8 9 lost+found
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem#
```

내 학번은 32200327 이므로 내가 찾아야할 할 디렉터리는 3이다.

```

root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# ls mnt/3
0  13 18 22 27 31 36 40 45 5 54 59 63 68 72 77 81 86 90 95
1  14 19 23 28 32 37 41 46 50 55 6 64 69 73 78 82 87 91 96
10 15 2 24 29 33 38 42 47 51 56 60 65 7 74 79 83 88 92 97
11 16 20 25 3 34 39 43 48 52 57 61 66 70 75 8 84 89 93 98
12 17 21 26 30 35 4 44 49 53 58 62 67 71 76 80 85 9 94 99
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem#

```

또한 디렉터리 3에 들어간 후 접근해야 하는 파일은 27, 72 이다.

각 파일에는 각각 4개의 block이 할당되어 있고, 여기에 내가 1개씩 block을 추가해준다.

```

root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# ls -l mnt/3/27
-rw-r--r-- 1 root root 12295 5월 27 01:44 mnt/3/27
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# ./apd mnt/3/27-13
Segmentation fault (core dumped)
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# ./apd mnt/3/27 13 3/27-13
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# ls -l mnt/3/27
-rw-r--r-- 1 root root 49160 5월 27 01:52 mnt/3/27
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# ls -l mnt/3/72
-rw-r--r-- 1 root root 12295 5월 27 01:44 mnt/3/72
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# ls -l mnt/3/72 13 3/72-13
ls: cannot access '13': No such file or directory
ls: cannot access '3/72-13': No such file or directory
-rw-r--r-- 1 root root 12295 5월 27 01:44 mnt/3/72
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# ./apd mnt/3/72 13 3/72-13
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# ls -l mnt/3/72
-rw-r--r-- 1 root root 49160 5월 27 01:54 mnt/3/72
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem#

```

## Super Block 영역 분석

해당 램디스크의 0x400byte 부터 0x100byte까지의 정보를 보여준다.

```

root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x400 /dev/ram
disk
00000400: 00800000 00000200 99190000 8ff70100 .....
00000410: f57f0000 00000000 02000000 02000000 .....
00000420: 00800000 00800000 00200000 2fae8f62 ..... ../..b
00000430: 2fae8f62 0100ffff 53ef0000 01000000 /..b....S.....
00000440: 08ae8f62 00000000 00000000 01000000 ...b.....
00000450: 00000000 0b000000 00010000 38000000 .....8...
00000460: 02000000 03000000 62f4e3f4 0879477c .....b....yG|
00000470: b611994f 7ddb890f 00000000 00000000 ...0}.....
00000480: 00000000 00000000 2f686f6d 652f6f73 ...../home/os
00000490: 6c61622f 32303232 5f444b55 5f4f532f lab/2022_DKU_OS/
000004a0: 6c616233 5f66696c 65737973 74656d2f lab3_filesystem/
000004b0: 6d6e7400 00000000 00000000 00000000 mnt.....
000004c0: 00000000 00000000 00000000 00001f00 .....
000004d0: 00000000 00000000 00000000 00000000 .....
000004e0: 00000000 00000000 00000000 d3872374 .....#t
000004f0: 3d2b45b8 b8e84e2a 838639f0 01000000 =+E...N*..9....
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem#

```

아래 자료를 참고하여 램디스크의 super block에서 제공하는 정보를 파악할 수 있다.

|     | 00                        | 01 | 02          | 03 | 04                       | 05 | 06             | 07 | 08                     | 09 | 0a            | 0b | 0c                      | 0d | 0e                 | 0f |         |  |
|-----|---------------------------|----|-------------|----|--------------------------|----|----------------|----|------------------------|----|---------------|----|-------------------------|----|--------------------|----|---------|--|
| 00  | inode count               |    |             |    | block count              |    |                |    | res block count        |    |               |    | free block count        |    |                    |    |         |  |
| 10  | free inode count          |    |             |    | first data block         |    |                |    | log block size         |    |               |    | log frag size           |    |                    |    |         |  |
| 20  | block per group           |    |             |    | frag per group           |    |                |    | inode per group        |    |               |    | mtime                   |    |                    |    |         |  |
| 30  | wtime                     |    |             |    | mount count              |    | max mount size |    | magic                  |    | state         |    | errors                  |    | minor version      |    |         |  |
| 40  | last check                |    |             |    | check interval           |    |                |    | creator OS             |    |               |    | major version           |    |                    |    |         |  |
| 50  | def_res uid               |    | def_res gid |    | first non-reserved inode |    |                |    | inode size             |    | block grp num |    | compatible feature flag |    |                    |    |         |  |
| 60  | incompatible feature flag |    |             |    | feature read only compat |    |                |    | uuid (16 byte)         |    |               |    |                         |    |                    |    |         |  |
| 70  |                           |    |             |    |                          |    |                |    | volume name (16 byte)  |    |               |    |                         |    |                    |    |         |  |
| 80  |                           |    |             |    |                          |    |                |    |                        |    |               |    |                         |    |                    |    |         |  |
| 90  |                           |    |             |    |                          |    |                |    |                        |    |               |    |                         |    |                    |    |         |  |
| a0  |                           |    |             |    |                          |    |                |    | last mounted (64 byte) |    |               |    |                         |    |                    |    |         |  |
| b0  |                           |    |             |    |                          |    |                |    |                        |    |               |    |                         |    |                    |    |         |  |
| c0  |                           |    |             |    |                          |    |                |    | algorithm usage bitmap |    |               |    | prealloc block          |    | prealloc dir block |    | padding |  |
| d0  | journal uuid              |    |             |    |                          |    |                |    |                        |    |               |    |                         |    |                    |    |         |  |
| e0  | journal inode number      |    |             |    | journal device           |    |                |    | last orphan            |    |               |    |                         |    |                    |    |         |  |
| f0  | hash seed (16 byte)       |    |             |    |                          |    |                |    |                        |    |               |    |                         |    | pad                |    | padding |  |
| 100 | default mount option      |    |             |    | first meta block         |    |                |    | default hash version   |    |               |    |                         |    |                    |    |         |  |

inode count : 0x8000

block count : 0x20000

log block size : 0x2

blocks per group : 0x8000

inodes per group : 0x2000

block group number : 0x0

## Group Descriptor Table 영역 분석

첫번째 Group Descriptor Table은 램디스크의 1블록 이후에 시작한다. 이때 1블록은 4KB = 0x1000 이다. Group Descriptor Table은 Bitmap 과 Inode의 위치를 가르키기 때문에 출력해주는 것이고, Group Descriptor Table의 첫 12byte에 표현되어 있기 때문에 램디스크의 0x1000 위치부터 0x1100 정도만 출력해준다.

```

root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x1000 /dev/ramdisk
00001000: 21000000 22000000 23000000 d47dc61e !..."....#....}..
00001010: 05000400 00000000 00000000 00000000 .....
00001020: 21800000 22800000 23800000 da7dd11e !..."....#....}..
00001030: 03000400 00000000 00000000 00000000 .....
00001040: 00000100 01000100 02000100 fa75361f .....u6.
00001050: 02000400 00000000 00000000 00000000 .....
00001060: 21800100 22800100 23800100 3976361f !..."....#...9v6.
00001070: 02000400 00000000 00000000 00000000 .....
00001080: 00000000 00000000 00000000 00000000 .....
00001090: 00000000 00000000 00000000 00000000 .....
000010a0: 00000000 00000000 00000000 00000000 .....
000010b0: 00000000 00000000 00000000 00000000 .....
000010c0: 00000000 00000000 00000000 00000000 .....
000010d0: 00000000 00000000 00000000 00000000 .....
000010e0: 00000000 00000000 00000000 00000000 .....
000010f0: 00000000 00000000 00000000 00000000 .....
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# █

```

Root 밑에 디렉토리가 있기 때문에 Root에 대한 Data가 있는 Block Group에 접근해야 한다.

그러기 위해서는 먼저 Root가 어느 Block Group에 있는지 알아야 하는데 Ext2에서 Root inode number는 2이고, 해당 램디스크의 inodes per group은 0x2000이다. 따라서 root's block group =  $(2-1)/0x2000 = 0$  이고, root's index =  $(2-1)\%0x2000 = 1$  이다.

위 사진 또한 첫번째 Block Group이므로 그대로 진행하면 된다.

## Inode Table 영역 분석

이제 root의 inode를 찾아가야 하는데 앞에서부터 block bitmap, inode bitmap, inode table의 위치를 가르킨다. 따라서 inode table은 0x23 부터 시작함을 알 수 있다.

Inode의 크기는 0x100 byte이고, root의 inode index는 1이므로 0x100부터가 root inode이다.

```

root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x1000 -s 0x23000 /dev/ramdisk
00023000: 00000000 00000000 08ae8f62 08ae8f62 .....b...b
00023010: 08ae8f62 00000000 00000000 00000000 ...b.....
00023020: 00000000 00000000 00000000 00000000 .....
00023030: 00000000 00000000 00000000 00000000 .....
00023040: 00000000 00000000 00000000 00000000 .....
00023050: 00000000 00000000 00000000 00000000 .....
00023060: 00000000 00000000 00000000 00000000 .....
00023070: 00000000 00000000 00000000 00000000 .....
00023080: 00000000 00000000 00000000 00000000 .....
00023090: 00000000 00000000 00000000 00000000 .....
000230a0: 00000000 00000000 00000000 00000000 .....
000230b0: 00000000 00000000 00000000 00000000 .....
000230c0: 00000000 00000000 00000000 00000000 .....
000230d0: 00000000 00000000 00000000 00000000 .....
000230e0: 00000000 00000000 00000000 00000000 .....
000230f0: 00000000 00000000 00000000 00000000 .....
00023100: ed410000 00100000 85ae8f62 7eae8f62 .A.....b~..b
00023110: 7eae8f62 00000000 00000d00 08000000 ~..b.....
00023120: 00000000 0a000000 23020000 00000000 .....#.....
00023130: 00000000 00000000 00000000 00000000 .....
00023140: 00000000 00000000 00000000 00000000 .....
00023150: 00000000 00000000 00000000 00000000 .....
00023160: 00000000 00000000 00000000 00000000 .....
00023170: 00000000 00000000 00000000 00000000 .....
00023180: 20000000 a4dfcce8 a4dfcce8 8c488b21 .....H.!
00023190: 08ae8f62 00000000 00000000 00000000 ...b.....
000231a0: 00000000 00000000 00000000 00000000 .....
000231b0: 00000000 00000000 00000000 00000000 .....
000231c0: 00000000 00000000 00000000 00000000 .....
000231d0: 00000000 00000000 00000000 00000000 .....

```



이제 root inode 테이블에서 root의 Data block 위치를 찾아서 이동해야 한다.

Root의 Data block은 block pointer 0 즉, 첫번째 block일 것이고, 아래 사진을 참고했을 때, root Data의 위치는 0x223 이다.

|    | 00                      | 01 | 02  | 03 | 04               | 05 | 06 | 07 | 08                       | 09 | 0a         | 0b | 0c                      | 0d | 0e | 0f |
|----|-------------------------|----|-----|----|------------------|----|----|----|--------------------------|----|------------|----|-------------------------|----|----|----|
| 00 | mode                    |    | uid |    | size             |    |    |    | access time              |    |            |    | change time             |    |    |    |
| 10 | modification time       |    |     |    | deletion time    |    |    |    | gid                      |    | link count |    | blocks                  |    |    |    |
| 20 | flags                   |    |     |    | OS description 1 |    |    |    |                          |    |            |    |                         |    |    |    |
| 30 | block pointer (60 byte) |    |     |    |                  |    |    |    |                          |    |            |    |                         |    |    |    |
| 40 |                         |    |     |    |                  |    |    |    |                          |    |            |    |                         |    |    |    |
| 50 |                         |    |     |    |                  |    |    |    |                          |    |            |    |                         |    |    |    |
| 60 |                         |    |     |    | generation       |    |    |    | file access control list |    |            |    | dir access control list |    |    |    |
| 70 | fragmentation blk addr  |    |     |    | OS description 2 |    |    |    |                          |    |            |    |                         |    |    |    |

## Data 영역 분석

3번 디렉토리의 inode number는 0xc 이고, file type도 0x2 이므로 디렉토리이다.

```
File Edit View Search Terminal Help
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x1000 -s 0x223000 /dev
/ramdisk
00223000: 02000000 0c000102 2e000000 02000000 .....
00223010: 0c000202 2e2e0000 0b000000 14000a02 .....
00223020: 6c6f7374 2b666f75 6e640000 01400000 lost+found...@..
00223030: 0c000102 30000000 01200000 0c000102 ....0....
00223040: 31000000 01600000 0c000102 32000000 1....`.....2...
00223050: 0c000000 0c000002 33000000 71000000 .....3...q...
00223060: 0c000102 34000000 66600000 0c000102 ....4...f`...
00223070: 35000000 66200000 0c000102 36000000 5...f .....6...
00223080: 66400000 0c000102 37000000 cb200000 f@.....7....
00223090: 0c000102 38000000 d6000000 680f0102 ...8.....h...
002230a0: 39000000 00000000 00000000 00000000 9.....
002230b0: 00000000 00000000 00000000 00000000 .....
002230c0: 00000000 00000000 00000000 00000000 .....
002230d0: 00000000 00000000 00000000 00000000 .....
002230e0: 00000000 00000000 00000000 00000000 .....
002230f0: 00000000 00000000 00000000 00000000 .....
00223100: 00000000 00000000 00000000 00000000 .....
00223110: 00000000 00000000 00000000 00000000 .....
00223120: 00000000 00000000 00000000 00000000 .....
00223130: 00000000 00000000 00000000 00000000 .....
00223140: 00000000 00000000 00000000 00000000 .....
00223150: 00000000 00000000 00000000 00000000 .....
00223160: 00000000 00000000 00000000 00000000 .....
00223170: 00000000 00000000 00000000 00000000 .....
00223180: 00000000 00000000 00000000 00000000 .....
00223190: 00000000 00000000 00000000 00000000 .....
002231a0: 00000000 00000000 00000000 00000000 .....
002231b0: 00000000 00000000 00000000 00000000 .....
002231c0: 00000000 00000000 00000000 00000000 .....
002231d0: 00000000 00000000 00000000 00000000 .....
```

따라서 3번 디렉토리가 속한 Block Group은  $(0xc - 1) / 2000 = 0$ 번 Block Group 이고, Inode Table Index는  $(0xc - 1) \% 2000 = 11$  이다.

## 디렉토리 접근하여 파일 찾기

따라서 인덱스 11로 이동하여 첫번째 block pointer로 이동하면 디렉터리 3이 나오는 것을 확인할 수 있다.

```
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x23c00 /dev/r
amdisk
00023c00: a4810000 06300000 7eae8f62 7fae8f62 .....0...b...b
00023c10: 7fae8f62 00000000 00000100 20000000 ...b.....
00023c20: 00000000 01000000 2c050100 0c090100 .....l...
00023c30: d0090100 340a0100 00000000 00000000 ....4.....
00023c40: 00000000 00000000 00000000 00000000 .....
00023c50: 00000000 00000000 00000000 00000000 .....
00023c60: 00000000 9eeb068f 00000000 00000000 .....
00023c70: 00000000 00000000 00000000 00000000 .....
00023c80: 20000000 10dc79c6 10dc79c6 58f913e3 .....y...y.X...
00023c90: 7eae8f62 58f913e3 00000000 00000000 ~..bX.....
00023ca0: 00000000 00000000 00000000 00000000 .....
00023cb0: 00000000 00000000 00000000 00000000 .....
00023cc0: 00000000 00000000 00000000 00000000 .....
00023cd0: 00000000 00000000 00000000 00000000 .....
00023ce0: 00000000 00000000 00000000 00000000 .....
00023cf0: 00000000 00000000 00000000 00000000 .....
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x1052c000 /de
v/ramdisk
1052c000: 332f302d 310a0000 00000000 00000000 3/0-1.....
1052c010: 00000000 00000000 00000000 00000000 .....
1052c020: 00000000 00000000 00000000 00000000 .....
1052c030: 00000000 00000000 00000000 00000000 .....
1052c040: 00000000 00000000 00000000 00000000 .....
1052c050: 00000000 00000000 00000000 00000000 .....
```

따라서 Indirect pointer block이 될 것이다. 첫번째 indirect block이 single indirect 이고, 따라서 1024개의 block을 가르킬 수 있기 때문에

내가 필요한 파일은 27, 72번 파일이다. 따라서 0x23c00에서 다시 각각 27번, 72번 뒤로 이동해야 한다. 먼저 27만큼 뒤로 이동한 후 첫번째 block pointer부터 4개는 direct pointer이기 때문에 해당 위치를 찾아가면 바로 블록을 찾을 수 있다.

```
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x25700 /dev/r
amdisk
00025700: a4810000 08c00000 7eae8f62 65b08f62 .....be..b
00025710: 65b08f62 00000000 00000100 30000000 .....6...
00025720: 00000000 01000000 47050100 87090100 .....G.....
00025730: eb090100 4f0a0100 00000000 00000000 ....0.....
00025740: 00000000 00000000 00000000 00000000 .....
00025750: 00000000 00000000 04020100 00000000 .....
00025760: 00000000 27f0f20f 00000000 00000000 .....
00025770: 00000000 00000000 00000000 00000000 .....
00025780: 20000000 f851a380 f851a380 b81f08e4 ....Q...Q....
00025790: 7eae8f62 b81f08e4 00000000 00000000 ~..b.....
000257a0: 00000000 00000000 00000000 00000000 .....
000257b0: 00000000 00000000 00000000 00000000 .....
000257c0: 00000000 00000000 00000000 00000000 .....
000257d0: 00000000 00000000 00000000 00000000 .....
000257e0: 00000000 00000000 00000000 00000000 .....
000257f0: 00000000 00000000 00000000 00000000 .....
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x1052c000 /de
v/ramdisk
1052c000: 332f302d 310a0000 00000000 00000000 3/0-1.....
1052c010: 00000000 00000000 00000000 00000000 .....
1052c020: 00000000 00000000 00000000 00000000 .....
1052c030: 00000000 00000000 00000000 00000000 .....
1052c040: 00000000 00000000 00000000 00000000 .....
1052c050: 00000000 00000000 00000000 00000000 .....
```



```

root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x10547000 /dev/randomisk
10547000: 332f3237 2d310a00 00000000 00000000 3/27-1..
10547010: 00000000 00000000 00000000 00000000 .....
10547020: 00000000 00000000 00000000 00000000 .....
10547030: 00000000 00000000 00000000 00000000 .....
10547040: 00000000 00000000 00000000 00000000 .....
10547050: 00000000 00000000 00000000 00000000 .....
10547060: 00000000 00000000 00000000 00000000 .....
10547070: 00000000 00000000 00000000 00000000 .....
10547080: 00000000 00000000 00000000 00000000 .....
10547090: 00000000 00000000 00000000 00000000 .....
105470a0: 00000000 00000000 00000000 00000000 .....
105470b0: 00000000 00000000 00000000 00000000 .....
105470c0: 00000000 00000000 00000000 00000000 .....
105470d0: 00000000 00000000 00000000 00000000 .....
105470e0: 00000000 00000000 00000000 00000000 .....
105470f0: 00000000 00000000 00000000 00000000 .....
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x10987000 /dev/randomisk
10987000: 332f3237 2d320a00 00000000 00000000 3/27-2..
10987010: 00000000 00000000 00000000 00000000 .....
10987020: 00000000 00000000 00000000 00000000 .....
10987030: 00000000 00000000 00000000 00000000 .....
10987040: 00000000 00000000 00000000 00000000 .....
10987050: 00000000 00000000 00000000 00000000 .....
10987060: 00000000 00000000 00000000 00000000 .....
10987070: 00000000 00000000 00000000 00000000 .....
10987080: 00000000 00000000 00000000 00000000 .....
10987090: 00000000 00000000 00000000 00000000 .....
109870a0: 00000000 00000000 00000000 00000000 .....
109870b0: 00000000 00000000 00000000 00000000 .....

```

```

root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x109eb000 /dev/randomisk
109eb000: 332f3237 2d330a00 00000000 00000000 3/27-3..
109eb010: 00000000 00000000 00000000 00000000 .....
109eb020: 00000000 00000000 00000000 00000000 .....
109eb030: 00000000 00000000 00000000 00000000 .....
109eb040: 00000000 00000000 00000000 00000000 .....
109eb050: 00000000 00000000 00000000 00000000 .....
109eb060: 00000000 00000000 00000000 00000000 .....
109eb070: 00000000 00000000 00000000 00000000 .....
109eb080: 00000000 00000000 00000000 00000000 .....
109eb090: 00000000 00000000 00000000 00000000 .....
109eb0a0: 00000000 00000000 00000000 00000000 .....
109eb0b0: 00000000 00000000 00000000 00000000 .....
109eb0c0: 00000000 00000000 00000000 00000000 .....
109eb0d0: 00000000 00000000 00000000 00000000 .....
109eb0e0: 00000000 00000000 00000000 00000000 .....
109eb0f0: 00000000 00000000 00000000 00000000 .....
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x10a4f000 /dev/randomisk
10a4f000: 332f3237 2d340a00 00000000 00000000 3/27-4..
10a4f010: 00000000 00000000 00000000 00000000 .....
10a4f020: 00000000 00000000 00000000 00000000 .....
10a4f030: 00000000 00000000 00000000 00000000 .....
10a4f040: 00000000 00000000 00000000 00000000 .....
10a4f050: 00000000 00000000 00000000 00000000 .....
10a4f060: 00000000 00000000 00000000 00000000 .....
10a4f070: 00000000 00000000 00000000 00000000 .....
10a4f080: 00000000 00000000 00000000 00000000 .....
10a4f090: 00000000 00000000 00000000 00000000 .....

```

하지만 direct block pointer는 12개이고, 13번째부터는 indirect block pointer가 된다. 또한 13번째부터 1024개는 single indirect block pointer이기 때문에 indirect block pointer가 가르키는 위치에서 하나 더 이동하면 된다.

```

root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x10204000 /dev/randomisk
10204000: a08b0100 00000000 00000000 00000000 .....
10204010: 00000000 00000000 00000000 00000000 .....
10204020: 00000000 00000000 00000000 00000000 .....
10204030: 00000000 00000000 00000000 00000000 .....
10204040: 00000000 00000000 00000000 00000000 .....
10204050: 00000000 00000000 00000000 00000000 .....
10204060: 00000000 00000000 00000000 00000000 .....
10204070: 00000000 00000000 00000000 00000000 .....
10204080: 00000000 00000000 00000000 00000000 .....
10204090: 00000000 00000000 00000000 00000000 .....
102040a0: 00000000 00000000 00000000 00000000 .....
102040b0: 00000000 00000000 00000000 00000000 .....
102040c0: 00000000 00000000 00000000 00000000 .....
102040d0: 00000000 00000000 00000000 00000000 .....
102040e0: 00000000 00000000 00000000 00000000 .....
102040f0: 00000000 00000000 00000000 00000000 .....
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x108ba000 /dev/randomisk
108ba000: 332f3237 2d31330a 00000000 00000000 3/27-13..
108ba010: 00000000 00000000 00000000 00000000 .....
108ba020: 00000000 00000000 00000000 00000000 .....
108ba030: 00000000 00000000 00000000 00000000 .....
108ba040: 00000000 00000000 00000000 00000000 .....
108ba050: 00000000 00000000 00000000 00000000 .....
108ba060: 00000000 00000000 00000000 00000000 .....
108ba070: 00000000 00000000 00000000 00000000 .....
108ba080: 00000000 00000000 00000000 00000000 .....

```

파일 72도 같은 방법으로 0x23c00에서 뒤로 72만큼 이동해 찾아준다.

```
File Edit View Search Terminal Help
105750a0: 00000000 00000000 00000000 00000000 .....
105750b0: 00000000 00000000 00000000 00000000 .....
105750c0: 00000000 00000000 00000000 00000000 .....
105750d0: 00000000 00000000 00000000 00000000 .....
105750e0: 00000000 00000000 00000000 00000000 .....
105750f0: 00000000 00000000 00000000 00000000 .....
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x28400 /dev/r
amdisk
00028400: a4810000 08c00000 7eae8f62 c1b08f62 .....~.b...b
00028410: c1b08f62 00000000 00000100 30000000 ...b.....0...
00028420: 00000000 01000000 74050100 b4090100 .....t.....
00028430: 180a0100 7c0a0100 00000000 00000000 ....|.....
00028440: 00000000 00000000 00000000 00000000 .....
00028450: 00000000 00000000 05020100 00000000 .....
00028460: 00000000 1bc377a1 00000000 00000000 .....w.....
00028470: 00000000 00000000 00000000 00000000 .....
00028480: 20000000 ecdad9c7 ecdad9c7 b81f08e4 .....
00028490: 7eae8f62 b81f08e4 00000000 00000000 ~.b.....
000284a0: 00000000 00000000 00000000 00000000 .....
000284b0: 00000000 00000000 00000000 00000000 .....
000284c0: 00000000 00000000 00000000 00000000 .....
000284d0: 00000000 00000000 00000000 00000000 .....
000284e0: 00000000 00000000 00000000 00000000 .....
000284f0: 00000000 00000000 00000000 00000000 .....

root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x10574000 /de
v/ramdisk
10574000: 332f3732 2d310a00 00000000 00000000 3/72-1.....
10574010: 00000000 00000000 00000000 00000000 .....
10574020: 00000000 00000000 00000000 00000000 .....
10574030: 00000000 00000000 00000000 00000000 .....
10574040: 00000000 00000000 00000000 00000000 .....
10574050: 00000000 00000000 00000000 00000000 .....
10574060: 00000000 00000000 00000000 00000000 .....
10574070: 00000000 00000000 00000000 00000000 .....
10574080: 00000000 00000000 00000000 00000000 .....
10574090: 00000000 00000000 00000000 00000000 .....

root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x109b4000 /de
v/ramdisk
109b4000: 332f3732 2d320a00 00000000 00000000 3/72-2.....
109b4010: 00000000 00000000 00000000 00000000 .....
109b4020: 00000000 00000000 00000000 00000000 .....
109b4030: 00000000 00000000 00000000 00000000 .....
109b4040: 00000000 00000000 00000000 00000000 .....
109b4050: 00000000 00000000 00000000 00000000 .....
109b4060: 00000000 00000000 00000000 00000000 .....
109b4070: 00000000 00000000 00000000 00000000 .....
109b4080: 00000000 00000000 00000000 00000000 .....
109b4090: 00000000 00000000 00000000 00000000 .....
109b40a0: 00000000 00000000 00000000 00000000 .....
109b40b0: 00000000 00000000 00000000 00000000 .....
109b40c0: 00000000 00000000 00000000 00000000 .....
109b40d0: 00000000 00000000 00000000 00000000 .....
109b40e0: 00000000 00000000 00000000 00000000 .....
109b40f0: 00000000 00000000 00000000 00000000 .....

root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x10a18000 /de
v/ramdisk
10a18000: 332f3732 2d330a00 00000000 00000000 3/72-3.....
10a18010: 00000000 00000000 00000000 00000000 .....
10a18020: 00000000 00000000 00000000 00000000 .....
10a18030: 00000000 00000000 00000000 00000000 .....
10a18040: 00000000 00000000 00000000 00000000 .....
10a18050: 00000000 00000000 00000000 00000000 .....
10a18060: 00000000 00000000 00000000 00000000 .....
10a18070: 00000000 00000000 00000000 00000000 .....
10a18080: 00000000 00000000 00000000 00000000 .....
10a18090: 00000000 00000000 00000000 00000000 .....
10a180a0: 00000000 00000000 00000000 00000000 .....
10a180b0: 00000000 00000000 00000000 00000000 .....
10a180c0: 00000000 00000000 00000000 00000000 .....
10a180d0: 00000000 00000000 00000000 00000000 .....
10a180e0: 00000000 00000000 00000000 00000000 .....
10a180f0: 00000000 00000000 00000000 00000000 .....
root@oslab:/home/oslab/2022_DKU_OS/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x10a7c000 /de
v/ramdisk
10a7c000: 332f3732 2d340a00 00000000 00000000 3/72-4.....
10a7c010: 00000000 00000000 00000000 00000000 .....
10a7c020: 00000000 00000000 00000000 00000000 .....
10a7c030: 00000000 00000000 00000000 00000000 .....
10a7c040: 00000000 00000000 00000000 00000000 .....
10a7c050: 00000000 00000000 00000000 00000000 .....
10a7c060: 00000000 00000000 00000000 00000000 .....
10a7c070: 00000000 00000000 00000000 00000000 .....
10a7c080: 00000000 00000000 00000000 00000000 .....
10a7c090: 00000000 00000000 00000000 00000000 .....
```

```

root@oslab:/home/oslab/2022_DKU_05/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x10205000 /dev/ramdisk
10205000: a18b0100 00000000 00000000 00000000 .....
10205010: 00000000 00000000 00000000 00000000 .....
10205020: 00000000 00000000 00000000 00000000 .....
10205030: 00000000 00000000 00000000 00000000 .....
10205040: 00000000 00000000 00000000 00000000 .....
10205050: 00000000 00000000 00000000 00000000 .....
10205060: 00000000 00000000 00000000 00000000 .....
10205070: 00000000 00000000 00000000 00000000 .....
10205080: 00000000 00000000 00000000 00000000 .....
10205090: 00000000 00000000 00000000 00000000 .....
102050a0: 00000000 00000000 00000000 00000000 .....
102050b0: 00000000 00000000 00000000 00000000 .....
102050c0: 00000000 00000000 00000000 00000000 .....
102050d0: 00000000 00000000 00000000 00000000 .....
102050e0: 00000000 00000000 00000000 00000000 .....
102050f0: 00000000 00000000 00000000 00000000 .....
root@oslab:/home/oslab/2022_DKU_05/lab3_filesystem# xxd -g 4 -l 0x100 -s 0x18ba1000 /dev/ramdisk
18ba1000: 332f3732 2d31330a 00000000 00000000 3/72-13.....
18ba1010: 00000000 00000000 00000000 00000000 .....
18ba1020: 00000000 00000000 00000000 00000000 .....
18ba1030: 00000000 00000000 00000000 00000000 .....
18ba1040: 00000000 00000000 00000000 00000000 .....
18ba1050: 00000000 00000000 00000000 00000000 .....
18ba1060: 00000000 00000000 00000000 00000000 .....
18ba1070: 00000000 00000000 00000000 00000000 .....
18ba1080: 00000000 00000000 00000000 00000000 .....
18ba1090: 00000000 00000000 00000000 00000000 .....

```

## Discussion

하나하나 따라가면서 실습하는 과정이 재미있었다. 사실 파일 시스템의 구조에 대해서 공부하기는 했지만 그냥 '그렇구나' 정도로 이해하고 넘어갈 뻔했는데 이렇게 직접 시스템 내부를 보고 또 block들이 어떻게 연결되어 있는지 따라가면서 파일 시스템의 구조를 확실히 이해하는데 더 도움이 되는 것 같았다. 처음에는 과정을 따라하면서 왜 블록에 5가 아닌 13을 추가하는지도 의문이었는데 indirect pointer를 찾아가는 과정을 실습하기 위함이라는 것도 깨달을 수 있었다.

다만 디렉토리를 찾는 과정에서 어려움이 있었다. 내가 찾아야 하는 디렉토리는 3이고, 해당 디렉토리의 inode는 0c000000이기 때문에 Block Group은 0, Inode table number은 11로 계산했다. 그러면 Block Group 0에서 index 0이 0x23000 이므로 index 11은 0x23b00이라고 생각했는데 디렉토리가 나오지 않아 한참을 헤매다 결국 0x23c00라는 것을 알아냈다. Inode table number 계산을 잘못했거나 이동을 잘못된 것인데 여전히 왜 이렇게 나오는지 알아내지 못한 점이 많이 아쉬웠기 때문에 과제 제출 이후에 시간을 내어 다른 친구들과 이부분에 대해 논의해볼 필요가 있을 것 같다.