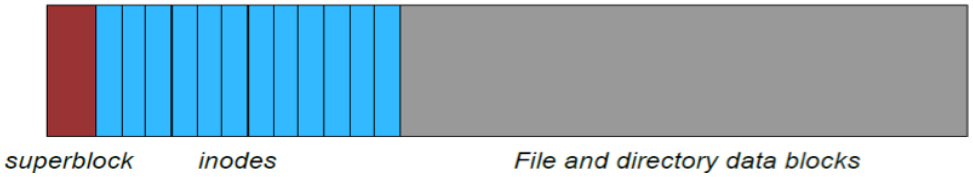
CS341#28 – inodes, permissions, modern fs

Reminder: Model disk layout for an ext2 filesystem. Inodes on disk have pointers to ~10 direct disk block entries, one indirect, one double indirect, one triple indirect block.



$2^{12} \times 2^{32} = 2^{44} B = 16\ TB$!!!

For ext2 with 4KB blocks and 32 bit addressing. What is the maximum supported disk size in bytes? But not enough today

Each inode entry is 128 bytes and during formatting 64KB is reserved for inode array. How many files and directories can you create? $2^{16} / 2^{7} = 2^{9}$ files and directories

For ext2 filesystem with 4KB blocks and 32 bit addressing , how large can a file be before a triple indirect block is required?

Big idea: Forget names of files: *The 'inode' **is** the file*

my.cat 123
name index
size file filename

What does the following do?

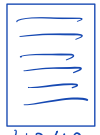
```
char mystery[PATH_MAX+1];
if (getcwd(mystery,PATH_MAX)) puts(mystery);?
```

read the current path in "mystery" and print it out. PATH_MAX is the limit

How do we implement a directory? (spot the mistake)

```
DIR* dirp = opendir(".");
while ((dp = readdir(dirp)) != NULL) {
   puts(dp->d_name);
   if (!strcmp(dp->d_name, name)) {
        return 1; /* Found */
   }
}
closedir(dirp);
return 0; /* Not Found */
```

dp → d_name
dp → d_ino (i number)
closedir(dirp)



in direct

4KB/4B = 1024 entries

4K X 1024X1024 = 4GB in double indirect

4 KBX 1024 = 4MB in the single indirect

How can I find the inode number of a file?

How do I find out meta- file information?

```
int stat(const char *path, struct stat *buf);
int fstat(int fd, struct stat *buf);
int lstat(const char *path, struct stat *buf);

struct stat {
 dev_t     st_dev;     ID of device containing file
 ino_t     st_ino;     inode number
 mode_t    st_mode;    protection & other info
 nlink_t   st_nlink;   number of hard links
 uid_t     st_uid;     user ID of owner
 gid_t     st_gid;     group ID of owner
 dev_t     st_rdev;    device ID (if special file)
 off_t     st_size;    total size, in bytes
 blksize_t st_blksize; blocksize for file system
 blkcnt_t  st_blocks;  number of 512B blocks allocated
 time_t    st_atime;   time of last access
 time_t    st_mtime;   time of last modification
 time_t    st_ctime;   time of last status change
};
```

who can read/write/execute? (rwx)
ref count!
(content)
(mode)
rwx

Users are integers!?
st_mtime vs st_ctime?

mymake.c ; compile iff source code is newer or target does not exist?

```
int s_ok = stat("prog.c", &src);
int t_ok = stat("a.out", &tgt);
        ↳ ≠0 when a.out doesn't exist
double delta = difftime(src.st_mtime, tgt.st_mtime)
// -ve if t1 before t2

if(t_ok ≠ 0 || s_ok ≠ 0 || delta ≥ 0) {
   puts("Compiling");
   system("gcc prog.c"); // = fork, exec shell, wait
} else  { puts("nothing to do"); }
```

Does the inode contain the filename [$10^{10^{10}}$ points]?

How can I have the same file appear in two different places in my file system?
(From code? Command?)
Reference counting?

rm = unlinking?

Changing File Permisssions?

chmod 644 /bin/sandwhich
chmod 755 /bin/sandwhich
chmod ugo-w /bin/sandwhich
chmod o-rx /bin/sandwhich

From code ... chmod(const char *path, mode_t mode);

What are the two "set uid bits" ?
set-user-ID-on-execution/set-group-ID-on-execution

Why are they useful? What common linux program uses this feature?

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ext3: Journaling. Able to rollback to a known good state.

ext4: Performance. Encryption. Better limits (e.g. #files per dir)
Case study: ext4 has the "delayed data-write problem"

```
fd=open("file", O_TRUNC); write(fd, data); close(fd);

fd=open("file.tmp");
write(fd, data);
close(fd);
rename("file.tmp", "file"); // Very happy in ext3
```

// but upgrading to ext4 : the rename could be completed before content is written to disk surface!

ZFS

1.1 Data integrity
1.2 RAID
1.3 Storage pools
1.4 ZFS cache: ARC (L1), L2ARC, ZIL
1.5 Gigantic Capacity (128bit model)
1.6 Copy-on-write transactional model
1.7 Snapshots and clones
1.8 Sending and receiving snapshots
1.9 Dynamic striping
1.10 Variable block sizes
1.11 Lightweight filesystem creation
1.12 Cache management
1.13 Adaptive endianness
1.14 Deduplication
1.15 Encryption

BtrFS

Extent based file storage
2^64 byte == 16 EiB maximum file size (practical limit is 8 EiB due to Linux VFS)
Space-efficient packing of small files
Space-efficient indexed directories
Dynamic inode allocation
Writable snapshots, read-only snapshots
Subvolumes (separate internal filesystem roots)
Checksums on data and metadata (crc32c)
Compression (zlib and LZO)
Integrated multiple device support
File Striping, File Mirroring, File Striping+Mirroring, Striping with Single and Dual Parity implementations
SSD (Flash storage) awareness (TRIM/Discard for reporting free blocks for reuse) and optimizations
Efficient Incremental Backup
Background scrub process for finding and fixing errors on files with redundant copies
Online filesystem defragmentation
Offline filesystem check
In-place conversion of existing ext3/4 file systems
Seed devices. Create a (readonly) filesystem that acts as a template to seed other Btrfs filesystems. The original filesystem and devices are included as a readonly starting point for the new filesystem. Using copy on write, all modifications are stored on different devices; the original is unchanged.
Subvolume-aware quota support
Send/receive of subvolume changes
Efficient incremental filesystem mirroring
Batch, or out-of-band deduplication (happens after writes, not during)