CSE 451: Operating Systems

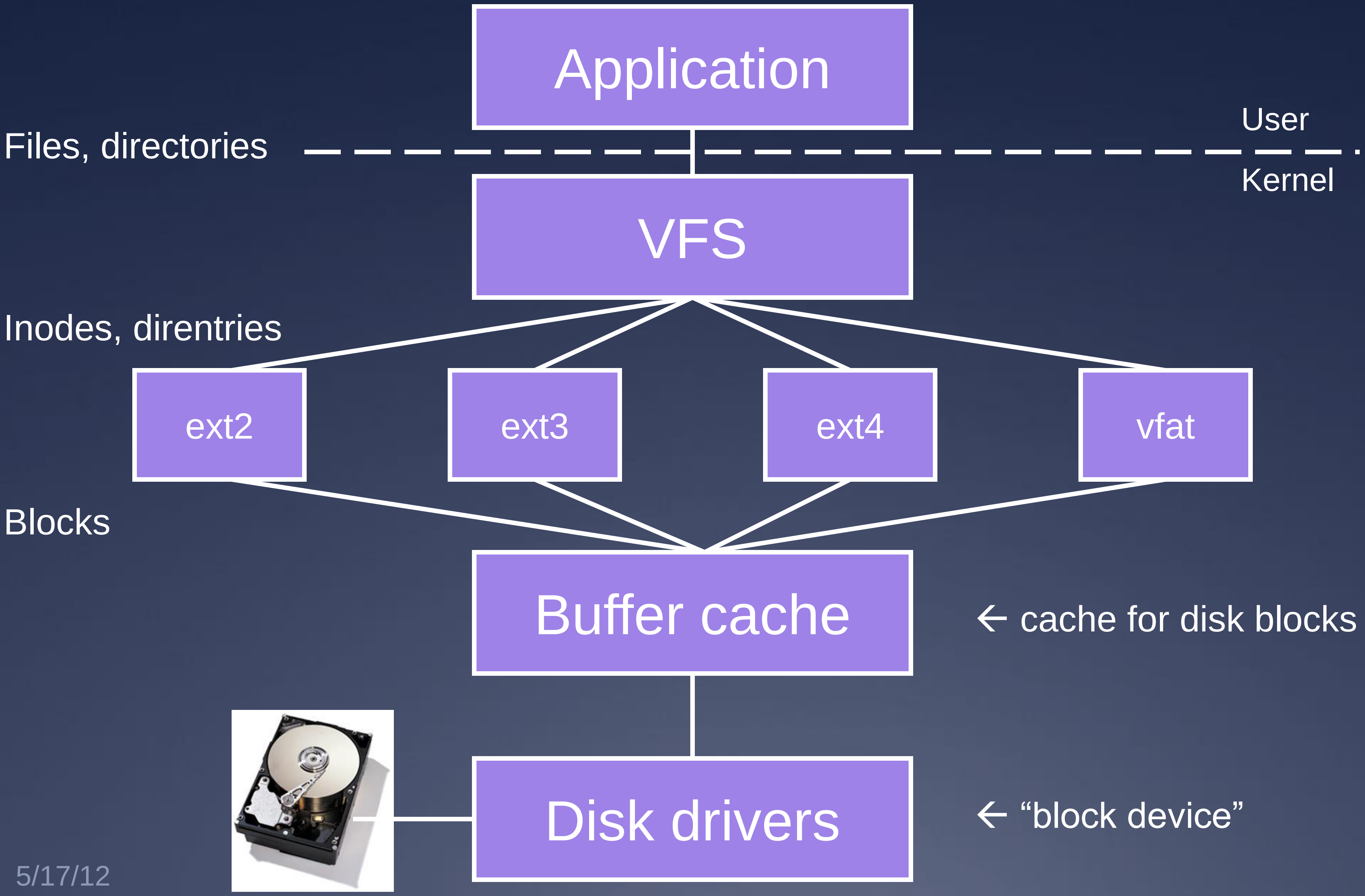
Section 8

Project 2b wrap-up, ext2, and Project 3

Project 2b

- Make sure to read thoroughly through the requirements for the writeup in part 6 and answer every question
- There are multiple ways of measuring throughput that you should discuss
  - Responses/second
  - Bytes transferred/second (average throughput per client and total average throughput)
- Any lingering questions?

Linux file system layers



Application

User

Files, directories

Kernel

VFS

Inodes, direntries

ext2

ext3

ext4

vfat

Blocks

Buffer cache

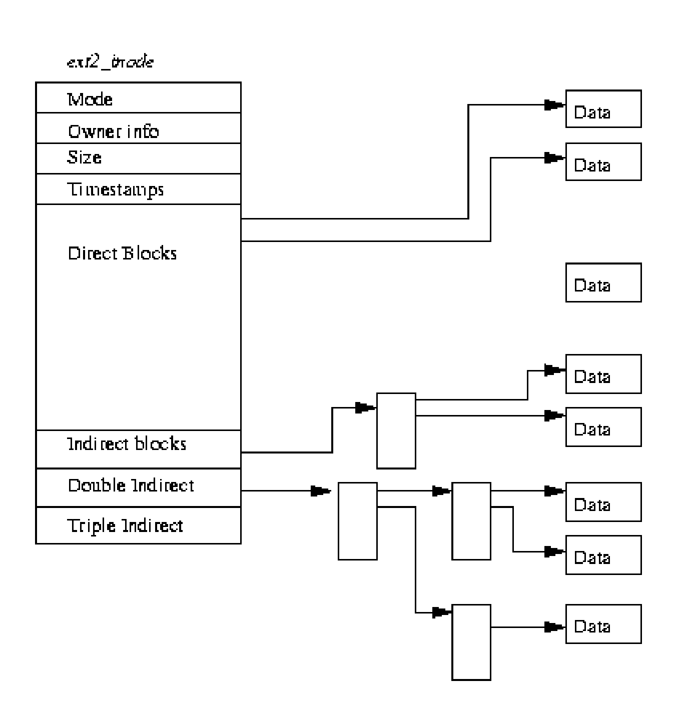
← cache for disk blocks

Disk drivers

← “block device”

Inodes

- *Inode*: a structure maintaining all metadata about a file (or directory)
  - Inode number (unique ID of inode)
  - Permissions, timestamps
  - Pointers to *data blocks*
- Inode does *not* contain: name of file
  - Where is it actually stored?
  - One or more file names can point (link) to the same inode. When will this occur?



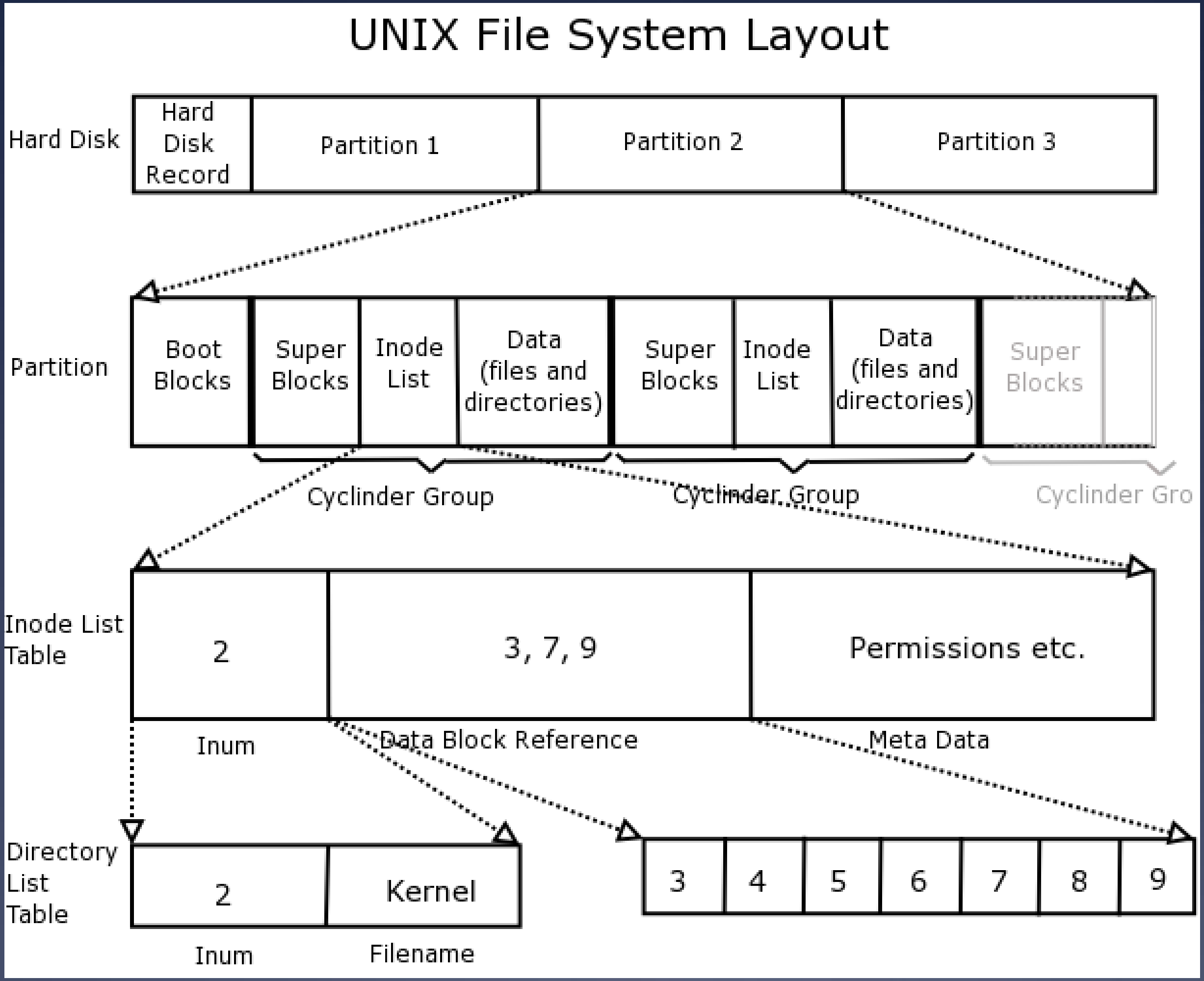
Inode structure

- Remember, inodes themselves are stored in blocks
  - What’s the size of the inode struct?
  - So how many inside a 1K block?
- Max number of inodes (max number of files) usually decided when file system is formatted
  - mkfs heuristic: create an inode for every three data blocks

Directories

- *Directory entry* (“dirent”): stores the file inode number, file name, and file type
  - Directory entries are stored in data blocks
- *Directory*: A list of directory entries
  - An inode with a directory i_mode attribute (check `LINUX_S_ISDIR()`) stores dirents in its data blocks

ext2 organization



Superblock

- Superblock always starts at byte 1024
- Master filesystem structure in ext2
- Stores global filesystem constants:
  - Block size
  - Inode size
  - Number of blocks
  - Number of inodes
  - …and much more
- Do not hardcode filesystem constants into your code! Use superblock information instead.

Block groups

- Block groups store:
  - A copy of the superblock (why?)
  - The block group descriptor table
    - Immediately proceeds the superblock
    - Contains the block numbers of the block bitmap, inode bitmap, and inode table among other things
  - A block bitmap (used vs. free blocks)
  - An inode bitmap (used vs. free inodes)
  - An inode table (the inodes themselves)
  - The actual data blocks

Data blocks

- Blocks for regular files contain file data
- Blocks for directories contain directory entries:

```
#define EXT2_NAME_LEN 255
struct ext2_dir_entry_2 {
  __u32 inode;    /* Inode number */
  __u16 rec_len;  /* Directory entry
                     length */
  __u8  name_len; /* Name length */
  __u8  file_type;
  char  name[EXT2_NAME_LEN]; /* File
                             name */
};
```

Data block for /

Dir. entry	Field	Value
0	Inode	1
	Name	“.”
1	Inode	1
	Name	“..”
2	Inode	2
	Name	“etc”
3	Inode	3
	Name	“bin”
4	Inode	0
	Name	0

Example data block usage

- For a 4MB file system with 1KB blocks, with hierarchy:

```
/
    etc
        passwd
        fstab
    bin
        sh
        date
```

File/Directory	Size	Data Blocks
/	4 entries + 1 null entry	1
/etc	4 entries + 1 null entry	1
/bin	4 entries + 1 null entry	1
/etc/passwd	1024 bytes	1
/etc/fstab	100 bytes	1
/bin/sh	10,000 bytes	10
/bin/date	5,000 bytes	5
	Total:	**20**

For more ext2 reading

- A master reference is available at http://www.nongnu.org/ext2-doc/ext2.html
- Some other helpful resources:
  - http://homepage.smc.edu/morgan_david/cs40/analyze-ext2.htm
  - http://eecs.wsu.edu/~cs460/cs560/ext2fs.html
  - Wikipedia also has a decent explanation: http://en.wikipedia.org/wiki/Ext2#ext2_data_structures

Project 3: Undelete

- Out: Friday 5/17 once I have it ready
- Due: Saturday 6/2 at 11:59pm
- Same groups you've been with previously
- Some serious understanding is required, so read, discuss with your teammates, read some more, discuss, plan, then execute

Project 3: Undelete

- Your task: recover deleted files in ext2 filesystems
- How is this possible?
  - Even if inode links are removed, inodes and data might still be present
  - Make a best attempt at recovery of lost files—some are corrupted and beyond hope, so you won’t be able to recover them

Project 3: Undelete

- Tools at your disposal:
  - A header file with common ext2 definitions
  - open(), read(), lseek(), write(), close()
    - This means you'll be doing direct file IO on a filesystem file
    - You are permitted to keep only a small fixed number of inodes in memory at once (otherwise recovery of large files would be infeasible)
  - A utility for creating and mounting ext2 filesystems of various sizes
  - A program for printing out block information for an ext2 filesystem file

Tips

- The filesystem creation tool requires at least 60 1kB blocks or it will fail
- Think carefully about how to tell whether an inode is deleted. (Hint: you'll need to use the inode bitmap)
- Do not hardcode any ext2 constants. Use only those provided in headers and those from the superblock

Tips

- Pete and I will give out some additional test files, but you should also create your own sample filesystems using the provided tool
- Make sure to restore the accessed and modified times of files as well as their contents
- Test filesystems with indirect data blocks
- Test your code by restoring filesystems with things like large deleted JPGs that are easy to check (visually) for corruption

Tips

- If your group emails a plan of your approach to the project to Pete and me by class next Wednesday 5/23, we will review it and give you feedback
  - Take advantage of this; it will save you a lot of grief leading up to the deadline
  - Writing a plan is a great way to force yourself to learn the concepts

Questions?