
FAT32 Utility Operations

Guide: rm and rmdir

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Outline

- Problem of orphaned data
- File removal walkthrough
- Directory removal walkthrough

Orphans

What is orphaned data?

- Orphaned data – data marked as valid in the file system that cannot be reached through the file system mechanisms
- How could this ever happen?

Orphan Example

- Suppose we want to delete a file
- It has
 - A directory entry with a first cluster number
 - Data clusters
 - Entries in the FAT

Orphan Example

FAT	
Index	1 2 3 4 5 6 7
Next Cluster	4 EoC

Dir Entry: First Cluster # 3

Cluster numbers	3 DATA
	4 DATA

Our sample file starts at cluster 3 and continues to cluster 4.

Orphan Example

- Normally when we want to find a file's contents, we start by reading its directory entry contents
 - What if we start deleting there?

Orphan Example

FAT	
Index	1 2 3 4 5 6 7
Next Cluster	4 EoC

Dir Entry: First Cluster # 3

Cluster numbers	3 DATA
	4 DATA

Step 1: Read the file's first cluster number into memory.

Orphan Example

FAT	
Index	1 2 3 4 5 6 7
Next Cluster	4 EoC

Step 2: Delete the file's directory entry.

Cluster numbers	3 DATA
	4 DATA

Orphan Example

FAT	
Index	1 2 3 4 5 6 7
Next Cluster	4 EoC



Step 3: Look up cluster 3 in the FAT.

Cluster numbers	3	DATA
	4	DATA

Orphan Example

FAT	
Index	1 2 3 4 5 6 7
Next Cluster	4 EoC



Step 4: Read the file's next cluster number into memory (4).

Cluster numbers	3	DATA
	4	DATA

Orphan Example

FAT	
Index	1 2 3 4 5 6 7
Next Cluster	4 EoC



Cluster numbers	3 DATA
	4 DATA

Orphan Example

- We just crashed and have to reboot the system
- Can the file system get to the data we were deleting?

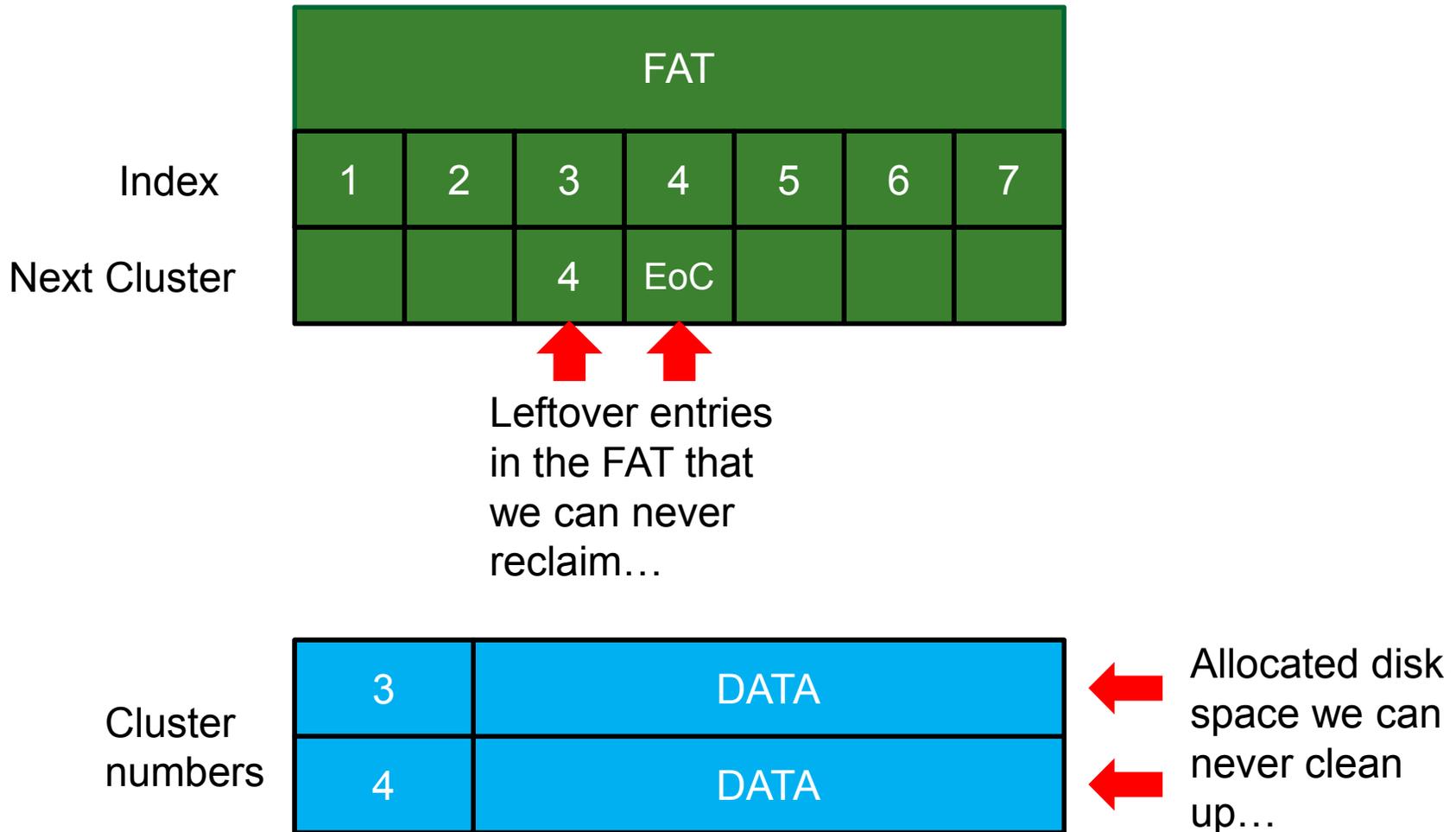
Orphan Example

FAT	
Index	1 2 3 4 5 6 7
Next Cluster	4 EoC

Cluster numbers	3 DATA
	4 DATA

We are now in trouble. Since we deleted the file's directory entry, we don't know where the file started...

Orphan Example



Preventing Orphans

- How can we avoid the chance of orphans while we delete?
- Answer: delete backwards!

Preventing Orphans

FAT	
Index	1 2 3 4 5 6 7
Next Cluster	4 EoC



Dir Entry: First Cluster # 3

Cluster numbers	3 DATA
	4 DATA

Step 1: Read through entire file until we find the last cluster entry for the file in the FAT

Preventing Orphans

FAT	
Index	1 2 3 4 5 6 7
Next Cluster	4



Dir Entry: First Cluster # 3

Cluster numbers	3	DATA
	4	DATA

Step 2: Mark the last cluster as free. What happens if we crash here?

Preventing Orphans

FAT	
Index	1 2 3 4 5 6 7
Next Cluster	4

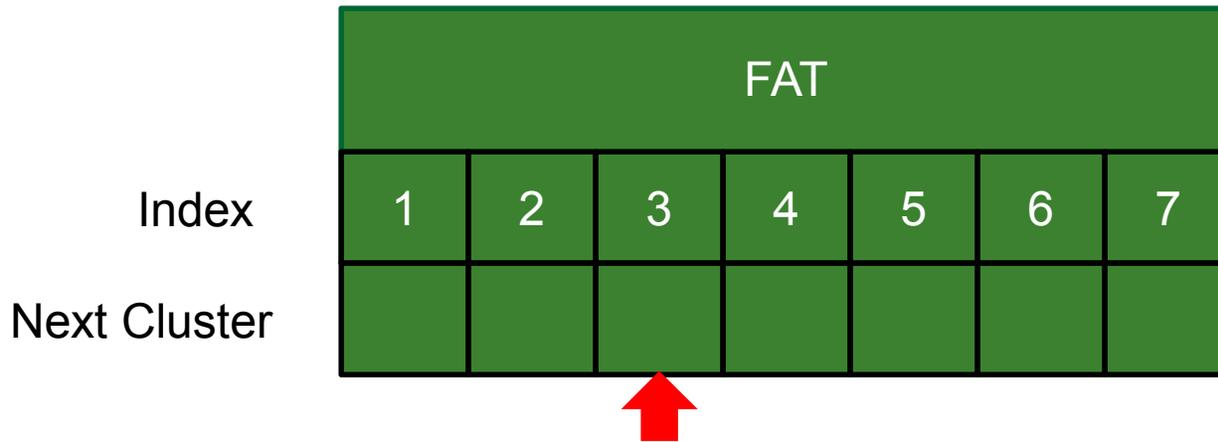


Dir Entry: First Cluster # 3

Cluster numbers	3	DATA
	4	DATA

Step 3: Find the new last file cluster in the FAT.

Preventing Orphans



Step 4: Mark the last cluster as free.

Dir Entry: First Cluster # 3

Cluster numbers	3	DATA
	4	DATA

Preventing Orphans

FAT	
Index	1 2 3 4 5 6 7
Next Cluster	

Step 5: Finally, if all the FAT entries for the file are marked free, delete the directory entry.

Cluster numbers	3 DATA
	4 DATA

Preventing Orphans

FAT	
Index	1 2 3 4 5 6 7
Next Cluster	

Cluster numbers	3 DATA
	4 DATA

Why don't we zero out the file's data?

File Data Leftovers

- Most file systems only update metadata upon deletion and leave old data as it was. Why?
 - ❑ Old data will just be overwritten later anyway by new, valid data
 - ❑ File system will never display old data to the user because it is no longer part of a file
 - ❑ It can take a significant amount of time to zero over large amounts of file data
 - ❑ Zeroing the data can cause extra wear on the device

File Data Leftovers

- File recovery utilities leverage this situation
 - Scans the file system for data clusters that are not currently allocated

File Deletion

rm operation

File Deletion : rm

1. Check that the file to removed is a file and does exist
 - Cannot use this utility command to delete a directory
2. Seek to the last cluster entry in the FAT
3. Mark the last cluster entry in the FAT with the free mark of 0x00000000
4. Repeat 2 and 3 until there are no more cluster entries in the FAT
5. Delete the file's directory entry

Deleting a Directory Entry

- Can just mark the first byte in the directory entry to symbolize deletion
 - If `DIR_Name[0] == 0xE5`, then the directory entry is free (no file or directory name in this entry)
 - If `DIR_Name[0] == 0x00`, then the directory entry is free (same as for `0xE5`), and there are no allocated directory entries after this one

Deleting a Directory Entry

```
user@cop4610: ~
00100580 41 73 00 65 00 72 00 69 00 61 00 0F 00 EF 6C 00 As.e.r.i.a....l.
00100590 69 00 7A 00 61 00 74 00 69 00 00 00 6F 00 6E 00 i.z.a.t.i...o.n.
001005A0 53 45 52 49 41 4C 7E 31 20 20 20 10 00 64 B2 6C SERIAL~1 ..d.l
001005B0 5C 3D 5C 3D 00 00 B2 6C 5C 3D 66 04 00 00 00 00 \=\=...l\=f.....
001005C0 E5 68 00 65 00 6C 00 6C 00 6F 00 0F 00 F1 2E 00 .h.e.l.l.o.....
001005D0 74 00 78 00 74 00 00 00 FF FF 00 00 FF FF FF FF t.x.t.....
001005E0 E5 45 4C 4C 4F 20 20 20 54 58 54 20 00 00 EB 61 .ELLO TXT ...a
001005F0 69 3D 69 3D 00 00 EB 61 69 3D 00 00 00 00 00 00 i=i=...ai=.....
00100600 2E 20 20 20 20 20 20 20 20 20 20 10 00 00 B2 6C . ....l
00100610 5C 3D 5C 3D 00 00 B2 6C 5C 3D 03 00 00 00 00 00 \=\=...l\=.....
00100620 2E 2E 20 20 20 20 20 20 20 20 10 00 00 B2 6C .. ....l
00100630 5C 3D 5C 3D 00 00 B2 6C 5C 3D 00 00 00 00 00 00 \=\=...l\=.....
00100640 41 68 00 00 00 00 00 00 00 00 0F 00 14 00 00 Ah.e.l.l.o.....
00100650 FF FF 00 00 00 00 00 00 FF FF FF FF .....
00100660 48 45 00 00 00 00 00 00 00 10 00 64 B2 6C HELLO ..d.l
00100670 5C 3D 00 00 00 00 00 00 00 00 00 00 00 00 \=\=...l\=.....
00100680 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
00100690 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
001006A0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
001006B0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
001006C0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
001006D0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
001006E0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
001006F0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
00100700 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
--- fat32.img --0x1005C0/0x4000000-----
```

Deleted directory entry
staring with 0xE5

Deleting a Directory Entry

```
user@cop4610: ~
00100580  41 73 00 65 00 72 00 69 00 61 00 0F 00 EF 6C 00  As.e.r.i.a....l.
00100590  69 00 7A 00 61 00 74 00 69 00 00 00 6F 00 6E 00  i.z.a.t.i...o.n.
001005A0  53 45 52 49 41 4C 7E 31 20 20 20 10 00 64 B2 6C  SERIAL~1  ..d.l
001005B0  5C 3D 5C 3D 00 00 B2 6C 5C 3D 66 04 00 00 00 00  \=\=...l\=f.....
001005C0  E5 68 00 65 00 6C 00 6C 00 6F 00 0F 00 F1 2E 00  .h.e.l.l.o.....
001005D0  74 00 78 00 74 00 00 00 FF FF 00 00 FF FF FF FF  t.x.t.....
001005E0  E5 45 4C 4C 4F 20 20 20 54 58 54 20 00 00 EB 61  .ELLO  TXT ...a
001005F0  69 3D 69 3D 00 00 EB 61 69 3D 00 00 00 00 00 00  i=i=...ai=.....
00100600  10 00 00 B2 6C 10 00 00 00 00 00 00 00 00 00 00  . ....l
00100610  \=\=...l\=f.....
00100620  10 00 00 B2 6C .. ....l
00100630  5C 3D 5C 3D 00 00 5C 3D 00 00 00 00 00 00 00 00  \=\=...l\=f.....
00100640  41 68 00 65 00 6C 00 6C 00 6F 00 0F 00 14 00 00  Ah.e.l.l.o.....
00100650  FF 00 00 FF FF FF FF  .....
00100660  48 45 4C 4C 4F 20 20 20 20 20 20 10 00 64 B2 6C  HELLO  ..d.l
00100670  5C 3D 5C 3D 00 00 B2 6C 5C 3D 04 00 00 00 00 00  \=\=...l\=f.....
00100680  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  .....
00100690  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  .....
001006A0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  .....
001006B0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  .....
001006C0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  .....
001006D0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  .....
001006E0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  .....
001006F0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  .....
00100700  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  .....
--- fat32.img --0x1005C0/0x4000000-----
```

Starts with 0x00, so no more directory entries in this cluster

00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

rm Use Cases

- Successful rm

```
/FILES/] ls  
. .. CONST.TXT EMPTY.TXT HELLO.TXT  
/FILES/] rm HELLO.TXT  
/FILES/]
```

- Unsuccessful rm

```
/FILES/] rm NOTHERE.TXT  
Error: does not exist  
/FILES/]
```

Directory Deletion

`rmdir`

Directory Deletion: rmdir

1. Check that directory to be removed is empty and is actually a directory
2. Go to step #2 for rm
 - Rest of directions just like deleting a file!

rmdir Use Cases

- **Successful rmdir**

```
/DIRS/] rmdir A  
/DIRS/]
```

- **Unsuccessful rmdir**

```
/DIRS/] rmdir B  
Error: directory not empty  
/DIRS/]
```

rmmdir Use Cases

- Unsuccessful rmmdir

```
/DIRS/] cd ..
```

```
/] rmmdir FATINFO.TXT
```

```
Error: not a directory
```

```
/]
```

Next Time

- Today's lecture is last recitation lecture 😞

Project 3 Submission Hints

- Make sure everything is included!
 - Points will be taken off if things are missing
- Make sure the project at least compiles
 - If it doesn't, it will get a 0.
- Please remove all executables and *.o files before submissions
- Only one person in a group needs to submit. Include the name of the group members in the README file.

Project 3 Submission Hints

- Follow the submission guidelines in the Project Description
- Submit via Blackboard
- No demo

Questions?

- Good luck with project 3 and finals!