

CIRCL - DFIR 1.0.2

Introduction: File System Forensics and Data Recovery



CIRCL *TLP:WHITE*

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Thanks to:

AusCERT



JISC



Overview

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1. File System Analysis - Overview

1.1 Abstract: Components of a file system

File System: - Organize data on a block device
 - Maintain an allocation table
 - Utilize meta data

-----		-----		-----				
V		V		V				
File Name		Metadata		Content				
-----				-----				
| file1.txt |	|	| Time stamps, |	13	| ..... |	5001		
| -> Inode: 13 |	|	| Owner, Group, |		| ..... |	5002		
-----	|	| Rights: MACB, |		| .... |	5003		
| file2.txt |	|	| 5001,5002,5003 |		| ..... |	5004		
| -> Inode: 14 |	|	| Size: 68 Byte |		| ..... |	5005		
-----	|	-----		| |	5006			
| file3.txt |	|	| Time stamps, |	14	| |	...			
| -> Inode: xyz |	|	| Owner, Group, |		| |	...			
-----	|	| Rights: MACB, |		| |	...			
| ..... |	|	| 5004,5005 |		| |	...			
| ..... |	|	| Size: 55 Byte |		| ( 32 Byte cluster ) |	5011			
-----				-----				
							
			0	8	16	24	31

Allocation table (Meta): 13, 14

Allocation table: 5001, 5002, 5003, 5004, 5005

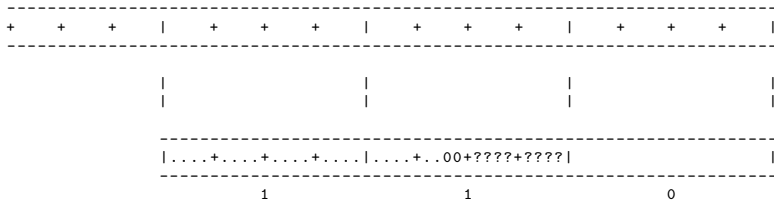
1.2 Delete a file: Allocated → Unallocated

File System: - Organize data on a block device
 - Maintain an allocation table
 - Utilize meta data

-----			-----		
V	V	V	V	V	V
File Name	Metadata		Content		
-----	-----		-----		...
| file1.txt |	| Time stamps, |	13	| ..... |	5001	
| -> Inode: 13 |	| Owner, Group, |		| ..... |	5002	
-----	| Rights: MACB, |		| .... |	5003	
| file2.txt XX |	| 5001,5002,5003 |		| ..... |	5004	
| -> Inode: 14 |	| Size: 68 Byte |		| ..... |	5005	
-----	-----		| ..... |	5006	
| file3.txt |	| Time stamps, |	14	| ..... |	...
| -> Inode: xyz |	| Owner, Group, |		| ..... |	...
-----	| Rights: MACB, |		| ..... |	...
| ..... |	| 5004,5005 |		| ..... |	...
| ..... |	| Size: 55 Byte |		| ( 32 Byte cluster ) |	5011	
-----	-----		-----		...
	| ..... |		| 0 | 8 | 16 | 24 | 31 |		
				

Allocation table (Meta): 13
 Allocation table: 5001, 5002, 5003

1.3 Slack space



0 = Unallocated
1 = Allocated

Evolution of slack space:

- Complete cluster is allocated to the file
- Until end of sector: Filled with zeros (or random memory --> RAM slack)
- Until end of cluster: Don't touch at all --> File slack
- Maybe there are rests of deleted file content.

1.4 Metadata based file recovery: Abstract

1. Create file: file1.txt

File Name	Inode	Content
| file1.txt |	| 7123, 7124 | 13	| ... | 7122
| -> Inode: 13 |	| ..... |	| H e l l o | 7123
| ----- |	| ----- |	| W o r l d | 7124
| ..... |	| | 14	| ... |
.....		...
-----	-----	-----
	
	

Allocation table (Meta): 13
Allocation table: 7123, 7124

2. Delete file: file1.txt

File Name	Inode	Content
| file1.txt XX |	| 7123, 7124 | 13	| ... | 7122
| -> Inode: 13 |	| ..... |	| H e l l o | 7123
| ----- |	| ----- |	| W o r l d | 7124
| ..... |	| | 14	| ... |
.....		...
-----	-----	-----
	
	

Allocation table (Meta): 14
Allocation table: 7122, 7123

1.4 Metadata based file recovery: Abstract

2. Delete file: file1.txt

File Name	Inode	Content
| file1.txt XX |	| 7123, 7124 | 13	| ... | 7122
| -> Inode: 13 |	| ..... |	| H e l l o | 7123
| ----- |	| ----- |	| W o r l d | 7124
| ..... |	| ..... | 14	| ... |
.....
-----
	
	

		Allocation table (Meta):
		Allocation table:

3. Create file: file2.txt (Partially overwrite data of file1.txt)

File Name	Inode	Content
| file1.txt XX |	| 7123, 7124 | 13	| T h i s i s | 7122
| -> Inode: 13 |	| ..... |	| P a u l a | 7123
| ----- |	| ----- |	| W o r l d | 7124
| file2.txt |	| 7122, 7123 | 14	| ... |
| -> Inode: 14 |	| ..... |	| ... |
-----
	
	

		Allocation table (Meta): 14
		Allocation table: 7122, 7123

1.4 Metadata based file recovery: Abstract

3. Create file: file2.txt (Partially overwrite data of file1.txt)

File Name	Inode	Content
| file1.txt XX |	| 7123, 7124 | 13	| T h i s i s | 7122
| -> Inode: 13 |	| ..... |	| P a u l a | 7123
| ----- |	| ----- |	| W o r l d | 7124
| file2.txt |	| 7122, 7123 | 14	| | ...
| -> Inode: 14 |	| |	| | ...
-----	-----	-----
	
	

Allocation table (Meta): 14
Allocation table: 7122, 7123

```
# Recovery of a (deleted) file
$ dd if=deleted.dd of=file2.txt bs=32 skip=7122 count=2
--> This is Paula
```

```
# Recovery of a reallocated file
$ dd if=deleted.dd of=file1.txt bs=32 skip=7123 count=2
--> Paula World
```

Discussion: What did we miss in this abstract example?

1.5 The Sleuth Kit

```
mmstat      # Volume system information
mmls        # List partition table
mmcat       # Cat a partition

fsstat      # File system information

fls         # List files and directories
fcats       # Cat a file
ffind       # Find filename of an inode

istat       # Inode information
ils         # List inodes
icat        # Cat an inode
ifind       # Find inode of a sector

blkstat     # Information of a data unit
blkls       # Output data units
blkcat      # Cat a data unit

jls         # List content of journal
jcat        # Cat a block from journal

mactime     # File system time line
srch_strings # Display printable characters
hfind       # Hash database lookup
....
```

1.6 Metadata based file recovery: The Sleuth Kit

3. Create file: file2.txt (Partially overwrite data of file1.txt)

File Name	Inode	Content
-----	-----	-----
| file1.txt XX |	| 7123, 7124 | 13	| T h i s i s | 7122
| -> Inode: 13 |	| ..... |	| P a u l a | 7123
| ----- |	| ----- |	| W o r l d | 7124
| file2.txt |	| 7122, 7123 | 14	| | ...
| -> Inode: 14 |	| |	| | ...
-----	-----	-----
	
	

Allocation table (Meta): 14
Allocation table: 7122, 7123

```
# Recovery of a (deleted) file
```

```
$ icat deleted 14 > file2.txt
```

```
--> This is Paula
```

```
# Recovery of a reallocated file
```

```
$ icat deleted 13 > file1.txt
```

```
--> Paula World
```

Exercise: Recover deleted files from /carving/deleted.dd

1.7 File slack and unallocated clusters

- Slack: Manual approach with dd

```
fsstat deleted.dd  
Cluster Size: 4096
```

```
fls -r deleted.dd
```

```
istat deleted.dd 72  
size: 12071  
1131 1132 1133
```

```
$ echo $(( (3*4096) - 12071 ))  
217
```

```
dd if=deleted.dd bs=4096 skip=1133 count=1 | xxd | less
```

- Slack: Automated approach with The Sleuthkit

```
blkls -s -b 4096 usb.dd
```

- Exercise: Does file recovery incl. slack?
- Blocks: With The Sleuthkit

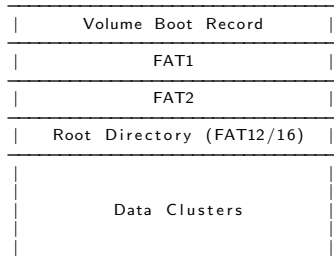
blkls -a -b 4096 deleted.dd | xxd | less	# Allocated blocks
blkls -A -b 4096 deleted.dd | xxd | less	# Unallocated blocks
blkls -e -b 4096 deleted.dd | xxd | less	# All blocks



2. FAT - File Allocation Table

2.1 FAT file system structure

- Layout and VBR Example



```
0000: eb3c 906d 6b66 732e 6661 7400 0204 0400
0010: 0200 0200 00f8 4000 2000 4000 0000 0000
0020: 0000 0100 8000 2974 6812 e84e 4f20 4e41
0030: 4d45 2020 2020 4641 5431 3620 2020 0elf
0040: be5b 7cac 22c0 740b 56b4 0ebb 0700 cd10
0050: 5eeb f032 e4cd 16cd 19eb fe54 6869 7320
.....
```

Exercise: fat16.dd = 33.554.432 Byte
Can you calculate the size of this FAT16?

- VBR interpretation

Offset	Length	Item	Interpretation
00 (0x00)	3	Jump bootstrap	JMP 62 NOP
03 (0x03)	8	OEM name	mkfs.fat
11 (0x0B)	2	Bytes/sector	0x0002 \longrightarrow 0x0200 = 512 Bytes
13 (0x0D)	1	Sectors/Cluster	0x04 = 2048 Bytes
14 (0x0E)	2	Sector before FS	0x0400 \longrightarrow 0x0004 = 4 Sectors
16 (0x10)	1	Copies of FAT	0x02
.....			

2.1 FAT Filesystem structures

- Layout and VBR Example

|	Volume Boot Record	|
|	FAT1	|
|	FAT2	|
|	Root Directory (FAT12/16)	|
|	Data Clusters	|

```
0000: eb3c 906d 6b66 732e 6661 7400 0204 0400
0010: 0200 0200 00f8 4000 2000 4000 0000 0000
0020: 0000 0100 8000 2974 6812 e84e 4f20 4e41
0030: 4d45 2020 2020 4641 5431 3620 2020 0e1f
0040: be5b 7cac 22c0 740b 56b4 0ebb 0700 cd10
0050: 5eeb f032 e4cd 16cd 19eb fe54 6869 7320
.....
```

Exercise: fat16.dd = 33.554.432 Byte
Can you calculate the size of this FAT16?

Solution: $33554432 / 512 / 4 * 2 / 512$

- VBR interpretation

Offset	Length	Item	Interpretation
00 (0x00)	3	Jump bootstrap	JMP 62 NOP
03 (0x03)	8	OEM name	mkfs.fat
11 (0x0B)	2	Bytes/sector	$0x0002 \rightarrow 0x0200 = 512$ Bytes
13 (0x0D)	1	Sectors/Cluster	$0x04 = 2048$ Bytes
14 (0x0E)	2	Sector before FS	$0x0400 \rightarrow 0x0004 = 4$ Sectors
16 (0x10)	1	Copies of FAT	0x02
.....			

2.2 FAT components simplified

Root Directory:

Name	Ext	Start	Size
file_A	txt	3	28
file_B	txt	7	4
.....			

Content of file:

Not part of Root directory

aaaaaaaaaaaaaaaaaaaaaaaaaaaa
bbbb

Data Clusters: (Size of 8 characters)

|	|	aaaaaaa	|	aaaaaaa	|	aaaaaaa	|	|	bbbb	|	|	|	|
0	1	2	3	4	5	6	7						
|	|	|	aaaa	|	|	|	|	|	|	|	|	|	|
8	9	A	B	C	D	E	F						

FAT: FAT16 in this example

| f8ff | ffff | 0000 | 0004 | 0005 | 000C | 0000 | ffff | 0000 | 0000 | 0000 | 0000 | ffff | 0000 |
0 1 2 3 4 5 6 7 8 9 A B C D
Reserved

2.3 FAT Filesystems

- Examine the FAT16

```
fsstat FAT/fat16.dd
.....
Total Range: 0 — 65535
* Reserved: 0 — 3
** Boot Sector: 0
* FAT 0: 4 — 67
* FAT 1: 68 — 131
* Data Area: 132 — 65535
** Root Directory: 132 — 163
** Cluster Area: 164 — 65535
.....
Sector Size: 512
Cluster Size: 2048
Total Cluster Range: 2 — 16344
```

- Test files:

```
5000 Nov 27 14:21 file01.txt
  50 Nov 28 10:38 file02.txt
```

```
file01.txt
.....AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA.....

file02.txt
.....XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.....
```

2.4 FAT file system analyzed

Root Directory: `dd if=FAT/fat16.dd skip=132 count=1 | xxd | less`

```
0020: 4649 4c45 3031 2020 5458 5420 0064 c46a  FILE01  TXT  .d.j
0030: 7b4d 7b4d 0000 c46a 7b4d 0300 8813 0000  {M{M...j{M.....
.....
0060: 4649 4c45 3032 2020 5458 5420 0064 104d  FILE02  TXT  .d.M
0070: 7c4d 7c4d 0000 104d 7c4d 0600 3200 0000  |M|M...M|M..2...
```

Offset	Length	Item	Interpretation
00 (0x00)	11	File Name	FILE01 TXT
.....			
26 (0x1A)	2	Low Cluster	0x0300 → 03
28 (0x1C)	4	Size in Bytes	0x8813 → 0x1388 = 5000

Data Clusters:

```
dd if=FAT/fat16.dd skip=164 count=4 | xxd | less .....
dd if=FAT/fat16.dd skip=168 count=4 | xxd | less AAAAAAAAAAAAAAAA
dd if=FAT/fat16.dd skip=172 count=4 | xxd | less AAAAAAAAAAAAAAAA
dd if=FAT/fat16.dd skip=176 count=4 | xxd | less AAAAAAAA.....
dd if=FAT/fat16.dd skip=180 count=4 | xxd | less XXXXX.....
```

FAT: `dd if=FAT/fat16.dd skip=4 count=1 | xxd | less`

```
0000: f8ff ffff 0000 0400 0500 ffff ffff 0000  ....
```

2.5 FAT Exercise: Delete file01.txt

Root Directory: `dd if=FAT/fat16.dd skip=132 count=1 | xxd | less`

```
0020: e549 4c45 3031 2020 5458 5420 0064 c46a  .ILE01 TXT .d.j
0030: 7b4d 7b4d 0000 c46a 7b4d 0300 8813 0000  {M{M...j{M.....
.....
0060: 4649 4c45 3032 2020 5458 5420 0064 104d  FILE02 TXT .d.M
0070: 7c4d 7c4d 0000 104d 7c4d 0600 3200 0000  |M|M...M|M..2...
```

Offset	Length	Item	Interpretation
00 (0x00)	11	File Name	.ILE01 TXT
.....			
26 (0x1A)	2	Low Cluster	0x0300 → 03
28 (0x1C)	4	Size in Bytes	0x8813 → 0x1388 = 5000

Data Clusters:

```
dd if=FAT/fat16.dd skip=164 count=4 | xxd | less .....
dd if=FAT/fat16.dd skip=168 count=4 | xxd | less AAAAAAAAAAAAAAAAAA
dd if=FAT/fat16.dd skip=172 count=4 | xxd | less AAAAAAAAAAAAAAAAAA
dd if=FAT/fat16.dd skip=176 count=4 | xxd | less AAAAAAAAA.....
dd if=FAT/fat16.dd skip=180 count=4 | xxd | less XXXXX.....
```

FAT: `dd if=FAT/fat16.dd skip=4 count=1 | xxd | less`

```
0000: f8ff ffff 0000 0000 0000 0000 ffff 0000  ....
```

2.6 FAT Exercise: Create subdirectory

Root Directory: `dd if=FAT/fat16.dd skip=132 count=1 | xxd | less`

```
0020: 5445 5354 4449 5220 2020 2010 0000 334d  TESTDIR      ...3M
0030: 7d4f 7d4f 0000 334d 7d4f 0300 0000 0000  }O}O...3M}O.....
.....
0060: 4649 4c45 3032 2020 5458 5420 0064 104d  FILE02  TXT  .d.M
0070: 7c4d 7c4d 0000 104d 7c4d 0600 3200 0000  |M|M...M|M..2...
```

Offset	Length	Item	Interpretation
00 (0x00)	11	File Name	TESTDIR
.....			
26 (0x1A)	2	Low Cluster	0x0300 —> 03
28 (0x1C)	4	Size in Bytes	0x00000000

Data Clusters: `dd if=FAT/fat16.dd skip=168 count=4 | xxd | less`

```
0000: 2e20 2020 2020 2020 2020 2010 0000 cc4c  .                ....L
0010: 7d4f 7d4f 0000 cc4c 7d4f 0300 0000 0000  }O}O...L}O.....
0020: 2e2e 2020 2020 2020 2020 2010 0000 cc4c  ..                ....L
0030: 7d4f 7d4f 0000 cc4c 7d4f 0000 0000 0000  }O}O...L}O.....
```

FAT: `dd if=FAT/fat16.dd skip=4 count=1 | xxd | less`

```
0000: f8ff ffff 0000 ffff 0000 0000 ffff 0000  .....
```

2.7 FAT Exercise: File slack

Root Directory: `dd if=FAT/fat16.dd skip=132 count=1 | xxd | less`

```
0020: 2e2e 2020 2020 2020 2020 2010 0000 cc4c  ..          ....L
0030: 7d4f 7d4f 0000 cc4c 7d4f 0000 0000 0000  }O}O...L}O.....
.....
0060: 4649 4c45 3737 2020 5458 5420 0000 334d  FILE77  TXT ..3M
0070: 7d4f 7d4f 0000 334d 7d4f 0400 2500 0000  }O}O..3M}O..%...
```

Offset	Length	Item	Interpretation
00 (0x00)	11	File Name	FILE77 TXT
.....			
26 (0x1A)	2	Low Cluster	0x0400 → 04
28 (0x1C)	4	Size in Bytes	0x25000000 → 0x25 == 37

Data Clusters:

```
dd if=FAT/fat16.dd skip=172 count=4 | xxd | less      1234567890ABCDEF
.....
AAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAA
dd if=FAT/fat16.dd skip=176 count=4 | xxd | less      AAAAAAAAAA.....
```

FAT: `dd if=FAT/fat16.dd skip=4 count=1 | xxd | less`

```
0000: f8ff ffff 0000 ffff ffff 0000 ffff 0000  .....
```

2.8 FAT Hiding data in Bad Sectors

- Preparation:

FAT: Mark a sector as bad

```
00800    F8FF FFFF 0000 0000 FFF7 0000 0000 0000 .....
.....
08800    F8FF FFFF 0000 0000 FFF7 0000 0000 0000 .....
```

→ The 3rd block is marked as bad sector

→ Calculate: Data cluster start at sector 164

Cluster 3 is marked as bad

$$164 + (2 * 4) = 172$$

→ We can use sector 172, 173, 174, 175 (cluster 3) to hide data

→ Byte offset: $172 * 512 = 88064$
= 0x15800

Data Cluster: Hide your secrets

```
15800    2020 2020 2020 2020 2020 2020 2020 2020
15810    4D79 2073 6563 7265 743A 2020 2020 2020    My secret:
15820    6131 6232 6333 6434 6535 6636 6737 6838    a1b2c3d4e5f6g7h8
15830    2020 2020 2020 2020 2020 2020 2020 2020
```

Copy file on disk

2.8 FAT Hiding data in Bad Sectors

- Analyze:

```
Root Directory: dd if=FAT/fat16.dd skip=132 count=1 | xxd | less
```

```
0020: 4649 4c45 5f4f 2020 5458 5420 0000 3637  FILE_O TXT ..67
0030: 8a50 8a50 0000 3637 8a50 0300 1027 0000  .P.P..67.P... '...
```

```
FAT: dd if=FAT/fat16.dd skip=4 count=1 | xxd | less
```

```
0000: f8ff ffff 0000 0500 fff7 0600 0700 0800  ....
0010: ffff 0000 0000 0000 0000 0000 0000 0000  ....
```

```
Data: dd if=fat16.test skip=168 count=4 | xxd | less
```

```
0000: 4f4f 4f4f 4f4f 4f4f 4f4f 4f4f 4f4f 4f4f  0000000000000000
```

```
Data: dd if=fat16.test skip=172 count=4 | xxd | less
```

```
0000: 2020 2020 2020 2020 2020 2020 2020 2020
0010: 4d79 2073 6563 7265 743a 2020 2020 2020  My secret:
0020: 6131 6232 6333 6434 6535 6636 6737 6838  a1b2c3d4e5f6g7h8
0030: 2020 2020 2020 2020 2020 2020 2020 2020
```

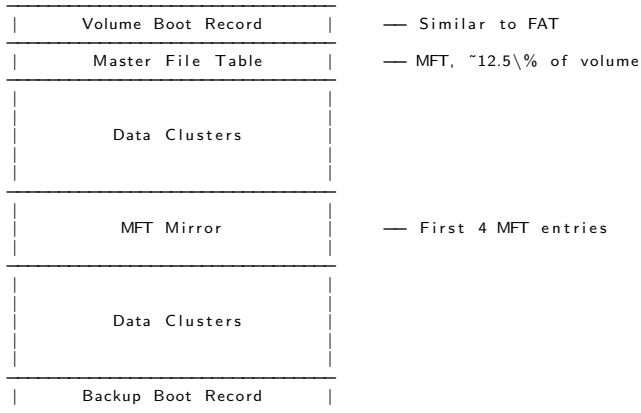
```
Data: dd if=fat16.test skip=176 count=4 | xxd | less
```

```
0000: 4f4f 4f4f 4f4f 4f4f 4f4f 4f4f 4f4f 4f4f  0000000000000000
```




3. NTFS - New Technology File System

3.1 NTFS file system structure



3.2 NTFS - Volume Boot Record

```

00000000: eb52 904e 5446 5320 2020 2000 0208 0000 .R.NTFS .....
00000010: 0000 0000 00f8 0000 0000 0000 0000 0000 .....
00000020: 0000 0000 8000 8000 fff7 0300 0000 0000 .....
00000030: 0400 0000 0000 0000 7f3f 0000 0000 0000 .....?.....
00000040: f600 0000 0100 0000 f92d c409 2fce 776f .....-../.wo
00000050: 0000 0000 0e1f be71 7cac 22c0 740b 56b4 .....q|."t.V.
00000060: 0ebb 0700 cd10 5eeb f032 e4cd 16cd 19eb .....^..2.....
00000070: fe54 6869 7320 6973 206e 6f74 2061 2062 .This is not a b
00000080: 6f6f 7461 626c 6520 6469 736b 2e20 506c ootable disk. Pl
00000090: 6561 7365 2069 6e73 6572 7420 6120 626f ease insert a bo
000000a0: 6f74 6162 6c65 2066 6c6f 7070 7920 616e otable floppy an
.....
000001e0: 0000 0000 0000 0000 0000 0000 0000 0000 .....
000001f0: 0000 0000 0000 0000 0000 0000 0000 55aa .....U.

```

Offset :	Length :	Description :	
00000000	3	JMP 52	Jump to bootcode at 54h
0000000B	2	00 02	Bytes per sector
0000000D	1	08	Sectors per cluster
00000028	8	fff7 0300	262135 sectors in total
00000030	8	04	MFT start cluster
00000040	1	f6	Size of MFT records: 10 \longrightarrow $2^{10} = 1.024$
00000054	426		Bootstrap code
000001FE	2	55 AA	End of sector signature

3.3 NTFS - Meta Files

- NTFS Meta Files

Entry	Filename	Description
0	\$MFT	MFT self reference
1	\$MFTMirr	Backup first 4 MFT entries
2	\$LogFile	Journal
3	\$Volume	Volume info table, version
4	\$AttrDef	Attribute definitions
5		Root Directory
6	\$Bitmap	Allocation status for each cluster
7	\$Boot	Boot Sector and boot code
8	\$BadClus	Bad Clusters
...		
23		

- Master File Table

- MFT maintain 1 record per file/directory
- Size: 1024 Bytes per record
- In NTFS everything is a file
 - Incl. meta files like \$MFT

3.4 MFT Record structure

Record Header	Attributes	End
| FILE	|	| FF FF FF FF |
0	55 56	1023

Record Header:

Signature: FILE

Link Count: File is listed in x directories

Is this a file or a directory

Size of the file

Deleted: Is the file already deleted

Attributes minium:

Attribute \$10: \$SIA — \$STANDARD_INFORMATION

Header \$10

Data Stream \$10

Attribute \$30: \$FNA — \$FILE_NAME

Header \$30

Data Stream \$30

Attribute \$80: \$Data

Header \$80

Data Stream \$80

.....

End of Recort: FF FF FF FF

Error Check Sequence

3.5 Investigating a Non-Resident file

```
$ ls -l
```

```
15000 Dez  9 16:09 small_text_file.txt
```

```
$ fsstat -o 2048 ntfs.raw
```

FILE SYSTEM INFORMATION

File System Type: NTFS

METADATA INFORMATION

First Cluster of MFT: 4
First Cluster of MFT Mirror: 16255
Size of MFT Entries: 1024 bytes

CONTENT INFORMATION

Sector Size: 512
Cluster Size: 4096
Total Cluster Range: 0 — 32510

```
$ fls -o 2048 ntfs.raw
```

```
r/r 73-128-2:      small_text_file.txt
```

3.5 Investigating a Non-Resident file

```
$ istat -o 2048 ntfs.raw 73
```

```
Attributes:
```

```
.....  
Type: $DATA (128-2)   Name: N/A   Non-Resident   size: 15000   init_size: 15000  
4169 4170 4171 4172
```

Exercise: Analyze data with TSK

```
$ icat -o 2048 ntfs.raw 73 | less
```

```
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA  
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA  
.....
```

Exercise: Analyze data manually with dd

```
$ dd if=ntfs.raw skip=$((2048 + 4169*8)) count=32 | xxd | less  
  
0000: 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAAAA  
0010: 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAAAA  
.....
```

3.5 Investigating a Non-Resident file

Demo: Analyze MFT record manually

```
$ dd if=ntfs.raw skip=$((2048 + 4*8 + 73*2)) | xxd | less

0000: 4649 4c45 3000 0300 0000 0000 0000 0000  FILE0 .....
0010: 0100 0100 3800 0100 b801 0000 0004 0000  ....8 .....
.....
0030: 1300 0000 0000 0000 1000 0000 4800 0000  ....H...
.....
0080: 3000 0000 8000 0000 0000 0000 0000 0300  0 .....
.....
0160: 0000 0001 0000 0000 8000 0000 4800 0000  ....H...
0170: 0100 4000 0000 0200 0000 0000 0000 0000  ..@ .....
0180: 0300 0000 0000 0000 4000 0000 0000 0000  .....@ .....
0190: 0040 0000 0000 0000 983a 0000 0000 0000  .@ .....
01a0: 983a 0000 0000 0000 2104 4910 0000 0000  :.....!.I .....
01b0: ffff ffff 0000 0000 ffff ffff 0000 0000  :.....
```

Analysis:

0000 — 0037	Attribute Header
0038 — 007F	1. Attribute \$10
0080 — 00FF	2. Attribute \$30
0100 — 0167	3. Attribute \$50
0168 — 01AF	4. Attribute \$80
01B0 — 01BF	End Marker

3.5 Investigating a Non-Resident file

Demo: Analyze MFT record manually

```
$ dd if=ntfs.raw skip=$((2048 + 4*8 + 73*2)) | xxd | less

0000: 4649 4c45 3000 0300 0000 0000 0000 0000 FILE0 .....
0010: 0100 0100 3800 0100 b801 0000 0004 0000 ....8 .....
.....
0030: 1300 0000 0000 0000 1000 0000 4800 0000 .....H...
.....
0080: 3000 0000 8000 0000 0000 0000 0000 0300 0.....
.....
0160: 0000 0001 0000 0000 8000 0000 4800 0000 .....H...
0170: 0100 4000 0000 0200 0000 0000 0000 0000 ..@.....
0180: 0300 0000 0000 0000 4000 0000 0000 0000 .....@.....
0190: 0040 0000 0000 0000 983a 0000 0000 0000 ..@.....:.....
01a0: 983a 0000 0000 0000 2104 4910 0000 0000 .....!.I....
01b0: ffff ffff 0000 0000 ffff ffff 0000 0000 .....
.....
```

Offset	Offset	Size	Value				Description :
0168	00	4	8000	0000	\$80	Attribute Type ID: \$80	
016C	04	4	4800	0000	72	Length of Attribute	
0170	08	1		01	1	Non-Resident Flag	
0190	28	8	0040	0000	0000	0000 16384	Allocated size
0198	30	8	983a	0000	0000	0000 15000	Actual size
01AA	42	2		4910	4169		Start cluster of data run

3.6 Investigating a Resident file

```
$ ls -l NTFS.Sub.Dir/sub.Dir.File1.txt
13 Dez  9 14:38 NTFS.Sub.Dir/sub.Dir.File1.txt

$ fls -r -o 2048 ntfs.raw
r/r 74-128-2:      sub.Dir.File1.txt

$ icat -o 2048 ntfs.raw 74
Attributes:
Type: $DATA (128-2)   Name: N/A   Resident   size: 13

$ icat -o 2048 ntfs.raw 74
Hello World!
```

Exercise:: Investigate Non-Resident Flag

```
$ dd if=ntfs.raw skip=$((2048 + 4*8 + 74*2)) count=2 | xxd | less

0160: 0000 0001 0000 0000 8000 0000 2800 0000 .....(...
0170: 0000 0000 0000 0200 0d00 0000 1800 0000 .....
0180: 4865 6c6c 6f20 576f 726c 6421 0a00 0000 Hello World!...
0190: ffff ffff 0000 0000 0000 0000 0000 0000 .....
```

3.7 Hiding Data

- Exercise: Information Exfiltration: Are there hidden data?
 - Windows Explorer
 - Show hidden files
 - CMD: `dir`
 - Open the file
 -
 - Other ideas?

- Answers:

>
>
>
>
>

- Creating ADS:

>
>
>
>
>

3.7 Hiding Data

- Exercise: Information Exfiltration: Are there hidden data?
 - Windows Explorer
 - Show hidden files
 - CMD: `dir`
 - Open the file
 -
 - Other ideas?

- Answers:

```
> dir /r          # Windows Vista +
>
> notepad G:\test.txt:123.txt
> mspaint G:\test.txt:123.jpg
```

- Creating ADS:

```
> File name syntax: <filename.ext>:<stream—name.ext>
>
> type 123.txt >> G:\test.txt:123.txt
> type "C:\Documents and Settings\All Users\Documents\My Pictures\
>      Sample Pictures\Sunset.jpg >> test.txt:123.jpg
```

3.7 Hiding Data

- History Alternate Data Stream:
 - OS/2 development by Microsoft and IBM
 - HPFS supported extended attributes in forks
 - NTFS forks renamed ADS
- Use of Alternate Data Stream:
 - Download zone of files
 - Replace of 'Thumbs.db' file in Windows 2000
 - File properties manually updated
- Exercise: Investigate MFT record after ADS creation
 1. Dump MFT record of the ADS hosting file
 2. Add an Alternate Data Stream to the file
 3. Dump MFT record of the ADS hosting file
 4. Analyze what has changed



4. NTFS - Advanced

4.1 Analyzing MFT Record manually

```
$ dd if=ntfs.raw skip=$((2048 + 4*8 + 74*2)) count=2 | xxd | less
```

```
0000: 4649 4c45 3000 0300 0000 0000 0000 0000  FILE0 .....
0010: 0100 0100 3800 0100 9801 0000 0004 0000  ....8 .....
0020: 0000 0000 0000 0000 0400 0000 4a00 0000  ....J...
0030: 0500 0000 0000 0000 1000 0000 4800 0000  ....H...
0040: 0000 0000 0000 0000 3000 0000 1800 0000  ....0 .....
0050: d376 a1e4 95ae d501 2580 a1e4 95ae d501  .v.....%.....
0060: 2580 a1e4 95ae d501 d376 a1e4 95ae d501  %.....v.....
0070: 2000 0000 0000 0000 0000 0000 0000 0000  .....
0080: 3000 0000 8000 0000 0000 0000 0000 0300  0.....
```

Offset	Size	Value				Description:
0000	4	4649	4c45	FILE		Signature
0006	2		0300	3		Entries in Fixup Area
0008	8	0000	0000	0000	0000	\$LogFile Seq Num
0010	2		0100	1		Seq Num: Use of record
0012	2		0100	1		Link Count
0014	2		3800	56		Offset to first attribute
0016	2		0100	file		file=1; directory=3
0018	4		9801	0000	408	Record size in use
001C	4		0004	0000	1024	Record size allocated
002C	4		4a00	0000	74	Record number
0031	3	0000	0000	0000	0	Fixup Area
0038	4	1000	0000	\$10		Attribute \$10
003C	4	4800	0000	0x48		Attribute size

4.1 Analyzing MFT Record manually

```
$ dd if=ntfs.raw skip=$((2048 + 4*8 + 74*2)) count=2 | xxd | less
```

```
0030: 0500 0000 0000 0000 1000 0000 4800 0000 .....H...
0040: 0000 0000 0000 0000 3000 0000 1800 0000 .....0.....
0050: d376 a1e4 95ae d501 2580 a1e4 95ae d501 .v.....%.....
0060: 2580 a1e4 95ae d501 d376 a1e4 95ae d501 %.....v.....
0070: 2000 0000 0000 0000 0000 0000 0000 0000 .....
0080: 3000 0000 8000 0000 0000 0000 0000 0300 0.....
0090: 6400 0000 1800 0100 4800 0000 0000 0200 d.....H.....
00a0: d376 a1e4 95ae d501 d376 a1e4 95ae d501 .v.....v.....
00b0: d376 a1e4 95ae d501 d376 a1e4 95ae d501 .v.....v.....
00c0: 1000 0000 0000 0000 0000 0000 0000 0000 .....
00d0: 2000 0000 0000 0000 1100 7300 7500 6200 .....s.u.b.
00e0: 5f00 4400 6900 7200 5f00 4600 6900 6c00 ..D.i.r...F.i.l.
00f0: 6500 3100 2e00 7400 7800 7400 1800 0000 e.1...t.x.t....
0100: 5000 0000 6800 0000 0000 0000 0000 0100 P...h.....
0110: 5000 0000 1800 0000 0100 0480 1400 0000 P.....
```

Offset	Size	Value			Description:
0038	4	1000	0000	\$10	\$STANDARD_INFORMATION
003C	4	4800	0000	0x48	Attribute size
0080	4	3000	0000	\$30	\$FILE_NAME
0084	4	8000	0000	0x80	Attribute size
0100	4	5000	0000	\$50	\$SECURITY_DESCRIPTOR
0104	4	6800	0000	0x68	Attribute size

4.1 Analyzing MFT Record manually

```

0100: 5000 0000 6800 0000 0000 0000 0000 0100 P...h.....
0110: 5000 0000 1800 0000 0100 0480 1400 0000 P.....
0120: 2400 0000 0000 0000 3400 0000 0102 0000 $.....4.....
0130: 0000 0005 2000 0000 2002 0000 0102 0000 .....
0140: 0000 0005 2000 0000 2002 0000 0200 1c00 .....
0150: 0100 0000 0003 1400 ff01 1f00 0101 0000 .....
0160: 0000 0001 0000 0000 8000 0000 2800 0000 .....(....
0170: 0000 0000 0000 0200 0d00 0000 1800 0000 .....
0180: 4865 6c6c 6f20 576f 726c 6421 0a00 0000 Hello World!....
0190: ffff ffff 0000 0000 0000 0000 0000 0000 .....

```

Offset	Size	Value			Description:
0100	4	5000	0000	\$50	\$SECURITY_DESCRIPTOR
0104	4	6800	0000	0x68	Attribute size
0168	4	8000	0000	\$80	\$SECURITY_DESCRIPTOR
016C	4	2800	0000	0x68	Attribute size
0170	1		00	0	Non-Resident Flag
0171	1		00	0	Name length
0172	2		0000	0	Name offset
0174	2		0000	0	Flags
0176	2		0200	2	Attribute ID
0178	4	0d00	0000	13	Attribute length
017C	2		1800	0x18	Attribute offset
017E	2		0000	0	Padding
0180	F				Content + Padding
0190	4	ffff	ffff	EOR	End Marker

4.2 Analyzing \$Bitmap file

- \$Bitmap file is located at MFT record 6
 - It contains the status of each cluster
 - Allocated or
 - Not allocated
 - Each bit represent a cluster
 - Example: Byte 1: 0x13 == 0001 0100
 - > Allocated Cluster: 3, 5
 - > Not allocated Clusters: 1, 2, 4, 6, 7, 8
 - Byte 12: 0xC1 == 1100 0001
 - > Allocated Cluster: 96, 102, 103
 - > Not allocated Clusters: 97, 98, 99, 100, 101
- # 12 * 8 = 96

Exercise: Calculate size of the \$Bitmap file

```
$ fsstat -o 2048 ntfs.raw
Cluster Size: 4096
Total Cluster Range: 0 - 32510
Total Sector Range: 0 - 260094
```

32510 Clusters —> 32510 Bits —> 4064 Byts —> 8 Sectors —> 1 Clusters

```
$ istat -o 2048 ntfs.raw 6
```

Attributes:

Type: \$DATA (128-1) Name: N/A Non-Resident size: 4064 init_size: 4064
4071

4.2 Analyzing \$Bitmap file

Investigate bitmap for cluster 29056–29063

Calculate bitmap position: $29056 / 8 = 3632 = 0xe30$

```
$ icat -o 2048 ntfs.raw 6 | xxd | less
00000e30: 0000 0000 0000 0000 0000 0000 0000 0000  ....
=====
```

Exercise: Create a 6 cluster test file to investigate \$Bitmap file

4.2 Analyzing \$Bitmap file

Investigate bitmap for cluster 29056–29063

Calculate bitmap position: $29056 / 8 = 3632 = 0xe30$

```
$ icat -o 2048 ntfs.raw 6 | xxd | less
00000e30: 0000 0000 0000 0000 0000 0000 0000 0000  ....
=====
```

Exercise: Create a 6 cluster test file to investigate \$Bitmap file

```
$ dd if=/dev/zero of=/cdrom/6-cluster.txt count=47
```

```
$ ls -lh /cdrom/6-cluster.txt
24064 Dez  5 12:10 /cdrom/6-cluster.txt
```

```
$ fls -o 2048 ntfs.raw
r/r 66-128-2:      6-cluster.txt
```

4.2 Analyzing \$Bitmap file

Investigate bitmap for cluster 29056–29063

Calculate bitmap position: $29056 / 8 = 3632 = 0xe30$

```
$ icat -o 2048 ntfs.raw 6 | xxd | less
00000e30: 0000 0000 0000 0000 0000 0000 0000 0000  ....
=====
```

Exercise: Create a 6 cluster test file to investigate \$Bitmap file

```
$ dd if=/dev/zero of=/cdrom/6-cluster.txt count=47
```

```
$ ls -lh /cdrom/6-cluster.txt
24064 Dez  5 12:10 /cdrom/6-cluster.txt
```

```
$ fls -o 2048 ntfs.raw
r/r 66-128-2:      6-cluster.txt
```

```
$ istat -o 2048 ntfs.raw 66
Attributes:
29056 29057 29058 29059 29060 29061
```

4.2 Analyzing \$Bitmap file

Investigate bitmap for cluster 29056–29063

Calculate bitmap position: $29056 / 8 = 3632 = 0xe30$

```
$ icat -o 2048 ntfs.raw 6 | xxd | less
00000e30: 0000 0000 0000 0000 0000 0000 0000 0000  ....
      ==
```

Exercise: Create a 6 cluster test file to investigate \$Bitmap file

```
$ dd if=/dev/zero of=/cdrom/6-cluster.txt count=47
```

```
$ ls -lh /cdrom/6-cluster.txt
24064 Dez  5 12:10 /cdrom/6-cluster.txt
```

```
$ fls -o 2048 ntfs.raw
r/r 66-128-2:      6-cluster.txt
```

```
$ istat -o 2048 ntfs.raw 66
Attributes:
29056 29057 29058 29059 29060 29061
```

```
$ icat -o 2048 ntfs.raw 6 | xxd | less
00000e30: 3f00 0000 0000 0000 0000 0000 0000 0000  ?.....
      ==
```

```
0011 1111
—> Allocated clusters: 29056, 29057, 29058, 29059, 29060, 29061
```

4.3 Deleting a file: What will change?

```
$ ls -l /cdrom/small_text_file.txt
15000 Dez  9 16:09 /cdrom/small_text_file.txt

$ fls -o 2048 ntfs.raw
r/r 73-128-2:      small_text_file.txt

$ istat -o 2048 ntfs.raw 73
Type: $DATA (128-2)   Name: N/A   Non-Resident   size: 15000   init_size: 15000
4169 4170 4171 4172
```

Data cluster:

```
$ dd if=ntfs.raw skip=$((2048 + 4169*8)) count=$((4*8)) | xxd | less
$ icat -o 2048 ntfs.raw 73 | xxd | less
```

MFT record 73:

```
$ dd if=ntfs.raw skip=$((2048 + 4*8 + 73*2)) count=2 | xxd | less
```

\$Bitmap file

```
4169 / 8 = 521.125  —> Byte 521 (0x209) in $Bitmap file for Cluster 4168 — 4175
                    —> - - - - -
                        x  x x x
```

```
$ icat -o 2048 ntfs.raw 6 | xxd | less
```

1. Extract the data
2. `$ rm /cdrom/small_text_file.txt`
3. Extract data and compare

4.3 Deleting a file: What will change?

Before delete:

Data cluster:

```
00000000: 4141 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAAAA
00000010: 4141 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAAAA
.....
00003a70: 4141 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAAAA
00003a80: 4141 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAAAA
00003a90: 4141 4141 4141 4141 0000 0000 0000 0000 0000  AAAAAAAAA .....
00003aa0: 0000 0000 0000 0000 0000 0000 0000 0000 0000  .....
00003ab0: 0000 0000 0000 0000 0000 0000 0000 0000 0000  .....
.....
00003fe0: 0000 0000 0000 0000 0000 0000 0000 0000 0000  .....
00003ff0: 0000 0000 0000 0000 0000 0000 0000 0000 0000  .....
```

\$Bitmap file:

```
00000200: ffff ffff ffff ffff ffff 0700 0000 0000  .....
                                     _____
```

0x209 = 1 1 1 1 1 1 1 1
 x x x x

4.3 Deleting a file: What will change?

After delete:

Data cluster:

```
00000000: 4141 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAAAA
00000010: 4141 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAAAA
.....
00003a70: 4141 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAAAA
00003a80: 4141 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAAAA
00003a90: 4141 4141 4141 4141 0000 0000 0000 0000 0000  AAAAAAAAA .....
00003aa0: 0000 0000 0000 0000 0000 0000 0000 0000 0000  .....
00003ab0: 0000 0000 0000 0000 0000 0000 0000 0000 0000  .....
.....
00003fe0: 0000 0000 0000 0000 0000 0000 0000 0000 0000  .....
00003ff0: 0000 0000 0000 0000 0000 0000 0000 0000 0000  .....
```

\$Bitmap file:

```
00000200: ffff ffff ffff ffff ffe1 0700 0000 0000  ....
                                               
```

0x209 = 1 1 1 0 0 0 0 1
 x x x x

4.3 Deleting a file: What will change?

Before delete:

MFT record:

```
00000000: 4649 4c45 3000 0300 0000 0000 0000 0000  FILE0 .....
00000010: 0100 0100 3800 0100 b801 0000 0004 0000  ....8.....
00000020: 0000 0000 0000 0000 0400 0000 4900 0000  ....I....
00000030: 1300 0000 0000 0000 1000 0000 4800 0000  ....H....
00000040: 0000 0000 0000 0000 3000 0000 1800 0000  ....0.....
.....
000003f0: 0000 0000 0000 0000 0000 0000 0000 1300  ....
```

offset:	size:	value:	description:
0010	2	1	Record sequence number
0012	2	1	Link count
0016	2	1	Record flag: 0000 = file deleted 0100 = file in use 0200 = dir deleted 0300 = dir in use
0030	2	1100	FixUp values
03fe	2	1300	CRC

4.3 Deleting a file: What will change?

After delete:

MFT record:

```
00000000: 4649 4c45 3000 0300 0000 0000 0000 0000  FILE0 .....
00000010: 0200 0000 3800 0000 b801 0000 0004 0000  ....8.....
00000020: 0000 0000 0000 0000 0400 0000 4900 0000  ....I....
00000030: 1400 0000 0000 0000 1000 0000 4800 0000  ....H....
00000040: 0000 0000 0000 0000 3000 0000 1800 0000  ....0.....
.....
000003f0: 0000 0000 0000 0000 0000 0000 0000 1400  ....
```

offset:	size:	value:	description:
0010	2	2	Record sequence number
0012	2	0	Link count
0016	2	0	Record flag: 0000 = file deleted 0100 = file in use 0200 = dir deleted 0300 = dir in use
0030	2	1400	FixUp values
03fe	2	1400	CRC

4.4 Directories

```
$ mkdir NTFS_Sub_Dir
$ echo "Hello World!" > NTFS_Sub_Dir/sub_Dir_File1.txt
$ ls -la NTFS_Sub_Dir/
    168 Dez  9 14:38 ./
    4096 Dez  9 14:37 ../
    13 Dez  9 14:38 sub_Dir_File1.txt
```

```
$ fls -r -o 2048 ntfs.raw
d/d 72-144-2: NTFS_Sub_Dir
r/r 74-128-2: sub_Dir_File1.txt
```

```
$ dd if=ntfs.raw skip=$((2048 + 4*8 + 72*2)) count=2 | xxd | less
00000000: 4649 4c45 3000 0300 0000 0000 0000 0000  FILE0.....
00000010: 0200 0100 3800 0300 3002 0000 0004 0000  ....8...0.....
00000020: 0000 0000 0000 0000 0400 0000 4800 0000  ....H...
00000030: 1000 7200 0000 0000 1000 0000 4800 0000  ..r.....H...
00000040: 0000 0000 0000 0000 3000 0000 1800 0000  ....0.....
00000050: 6e9d 97c1 95ae d501 5877 a1e4 95ae d501  n.....Xw.....
00000060: 5877 a1e4 95ae d501 c624 dded 95ae d501  Xw.....$.
00000070: 2000 0000 0000 0000 0000 0000 0000 0000  .....
```

Offset:	Length:	Value:	Description:
00000000	4	FILE	Record header signature
00000014	2	3800	Pointer to first attribute
00000016	2	0300	Record flag: 3 = directory in use
00000038	4	1000 0000	Standard Information
0000003C	4	4800 0000	Size of the attribute (total)

4.4 Directories

```
$ dd if=ntfs.raw skip=$((2048 + 4*8 + 72*2)) count=2 | xxd | less
00000080: 3000 0000 7800 0000 0000 0000 0000 0300  0...x.....
.....
000000d0: 2000 0010 0000 0000 0c00 4e00 5400 4600  ....N.T.F.
000000e0: 5300 5f00 5300 7500 6200 5f00 4400 6900  S...S.u.b...D.i.
000000f0: 7200 1800 0000 0200 5000 0000 6800 0000  r.....P...h...
.....
00000160: 9000 0000 c800 0000 0004 1800 0000 0200  ....
00000170: a800 0000 2000 0000 2400 4900 3300 3000  ....$.l.3.0.
00000180: 3000 0000 0100 0000 0010 0000 0100 0000  0.....
00000190: 1000 0000 9800 0000 9800 0000 0000 0000  ....
000001a0: 4a00 0000 0000 0100 7800 6400 0000 0000  J.....x.d....
000001b0: 4800 0000 0000 0200 d376 a1e4 95ae d501  H.....v.....
000001c0: 2580 a1e4 95ae d501 2580 a1e4 95ae d501  %.....%.....
000001d0: d376 a1e4 95ae d501 1000 0000 0000 0000  .v.....
000001e0: 0d00 0000 0000 0000 2000 0000 0000 0000  ....
000001f0: 1100 7300 7500 6200 5f00 4400 6900 1000  ..s.u.b...D.i...
00000200: 5f00 4600 6900 6c00 6500 3100 2e00 7400  _..F.i.l.e.1...t.
00000210: 7800 7400 0000 0000 0000 0000 0000 0000  x.t.....
00000220: 1000 0000 0200 0000 ffff ffff 0000 0000  .....
```

Offset :	Length :	Value :	Description :
00000080	4	3000 0000	\$FILE_NAME
00000084	4	7800 0000	Size of the attribute (total)
00000088	1	0000	Resident
00000160	4	9000 0000	\$INDEX_ROOT



5. File System Time Line

5.1 Time stamps: Nomenclature

- FAT
 - MAC times
 - M time: Content last Modified
 - A time: Content last Accessed
 - C time: File Created
- NTFS
 - MACE times
 - M time: Content last Modified
 - A time: Content last Accessed
 - C time: File Created
 - E-time: MFT Entry last modified
 - MACB times
 - M time: Content last Modified
 - A time: Content last Accessed
 - C time: MFT record last Changed
 - B-time: File created (Born)

5.2 Time stamps: Example

```
$ istat -o 2048 ntfs.raw 73
```

```
MFT Entry Header Values:
```

```
Entry: 73          Sequence: 2
```

```
$LogFile Sequence Number: 0
```

```
Not Allocated File
```

```
Links: 0
```

```
$STANDARD_INFORMATION Attribute Values:
```

```
Flags: Archive
```

```
Owner ID: 0
```

```
Security ID: 0  ()
```

```
Created:          2019-12-02 16:25:22.099440400 (CET)
```

```
File Modified:    2019-12-09 16:09:46.183651100 (CET)
```

```
MFT Modified:     2019-12-09 16:09:46.183651100 (CET)
```

```
Accessed:         2019-12-02 16:25:22.099440400 (CET)
```

```
$FILE_NAME Attribute Values:
```

```
Flags: Archive
```

```
Name: small_text_file.txt
```

```
Parent MFT Entry: 5          Sequence: 5
```

```
Allocated Size: 16384      Actual Size: 0
```

```
Created:          2019-12-02 16:25:22.099440400 (CET)
```

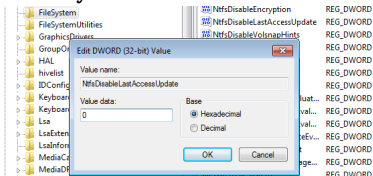
```
File Modified:    2019-12-02 16:25:22.099440400 (CET)
```

```
MFT Modified:     2019-12-02 16:25:22.099440400 (CET)
```

```
Accessed:         2019-12-02 16:25:22.099440400 (CET)
```


5.3 Last Access Time

- Updated in memory, written to disk after $\approx 1h$
- As of Win Vista
 - Not updated per default
 - `HKEY_LOCAL_MACHINE/SYSTEM/CurrentControlSet/Control/FileSystem/NtfsDisableLastAccessUpdate`



- Performance reasons
- Good for file server
- Still updated some times
 - File new created
 - File copied
 - File moved

5.4 Time Line: Exercise

Reproduce file system activities

Thu Jun 27 2013 12:23:08	113 ...b	35-128-1 c:/time-01.txt
Thu Jun 27 2013 12:24:20	75 m.cb	37-128-1 c:/time-02.txt
Thu Jun 27 2013 12:25:24	75 m.cb	38-128-1 c:/time-03.txt
	75 m...	41-128-1 c:/time-03 - Copy.txt
Thu Jun 27 2013 12:26:05	75 m..b	39-128-1 c:/time-44.txt
Thu Jun 27 2013 12:27:00	75 macb	40-128-1 c:/time-05.txt (deleted)
Thu Jun 27 2013 12:33:50	113 m.c.	35-128-1 c:/time-01.txt
Thu Jun 27 2013 13:07:52	75 .acb	41-128-1 c:/time-03 - Copy.txt
Thu Jun 27 2013 13:10:36	75 ..c.	39-128-1 c:/time-44.txt
Thu Jun 27 2013 13:14:20	20 m...	42-128-1 c:/time-06.txt
Thu Jun 27 2013 13:56:30	20 .acb	42-128-1 c:/time-06.txt

File: time-01.txt

Thu Jun 27 2013 12:23:08	113 ...b	35-128-1 c:/time-01.txt
Thu Jun 27 2013 12:33:50	113 m.c.	35-128-1 c:/time-01.txt

File: time-02.txt

Thu Jun 27 2013 12:24:20	75 m.cb	37-128-1 c:/time-02.txt
--------------------------	---------	-------------------------

5.4 Time Line: Exercise

Reproduce file system activities

Thu Jun 27 2013 12:23:08	113	...b	35-128-1	c:/time-01.txt
Thu Jun 27 2013 12:24:20	75	m.cb	37-128-1	c:/time-02.txt
Thu Jun 27 2013 12:25:24	75	m.cb	38-128-1	c:/time-03.txt
	75	m...	41-128-1	c:/time-03 - Copy.txt
Thu Jun 27 2013 12:26:05	75	m..b	39-128-1	c:/time-44.txt
Thu Jun 27 2013 12:27:00	75	macb	40-128-1	c:/time-05.txt (deleted)
Thu Jun 27 2013 12:33:50	113	m.c.	35-128-1	c:/time-01.txt
Thu Jun 27 2013 13:07:52	75	.acb	41-128-1	c:/time-03 - Copy.txt
Thu Jun 27 2013 13:10:36	75	..c.	39-128-1	c:/time-44.txt
Thu Jun 27 2013 13:14:20	20	m...	42-128-1	c:/time-06.txt
Thu Jun 27 2013 13:56:30	20	.acb	42-128-1	c:/time-06.txt

File: time-03.txt, time-03 - Copy.txt

Thu Jun 27 2013 12:25:24	75	m.cb	38-128-1	c:/time-03.txt
	75	m...	41-128-1	c:/time-03 - Copy.txt
Thu Jun 27 2013 13:07:52	75	.acb	41-128-1	c:/time-03 - Copy.txt

File: time-02.txt

Thu Jun 27 2013 12:26:05	75	m..b	39-128-1	c:/time-44.txt
Thu Jun 27 2013 13:10:36	75	..c.	39-128-1	c:/time-44.txt

5.4 Time Line: Exercise

Reproduce file system activities

Thu Jun 27 2013 12:23:08	113 ...b	35-128-1 c:/time-01.txt
Thu Jun 27 2013 12:24:20	75 m.cb	37-128-1 c:/time-02.txt
Thu Jun 27 2013 12:25:24	75 m.cb	38-128-1 c:/time-03.txt
	75 m...	41-128-1 c:/time-03 - Copy.txt
Thu Jun 27 2013 12:26:05	75 m..b	39-128-1 c:/time-44.txt
Thu Jun 27 2013 12:27:00	75 macb	40-128-1 c:/time-05.txt (deleted)
Thu Jun 27 2013 12:33:50	113 m.c.	35-128-1 c:/time-01.txt
Thu Jun 27 2013 13:07:52	75 .acb	41-128-1 c:/time-03 - Copy.txt
Thu Jun 27 2013 13:10:36	75 ..c.	39-128-1 c:/time-44.txt
Thu Jun 27 2013 13:14:20	20 m...	42-128-1 c:/time-06.txt
Thu Jun 27 2013 13:56:30	20 .acb	42-128-1 c:/time-06.txt

File: time-05.txt

Thu Jun 27 2013 12:27:00	75 macb	40-128-1 c:/time-05.txt (deleted)
--------------------------	---------	-----------------------------------

File: time-06.txt

Thu Jun 27 2013 13:14:20	20 m...	42-128-1 c:/time-06.txt
Thu Jun 27 2013 13:56:30	20 .acb	42-128-1 c:/time-06.txt

5.4 Time Line: Exercise

Summary: What could we reproduce

Yes/No

File: time-01.txt

- | | |
|--|-----|
| 1. 12:23:08 time-01.txt → new create | Yes |
| 6. 12:29:07 time-01.txt → modified content | No |
| 7. 12:33:50 time-01.txt → 2nd modification | Yes |

time-02.txt

- | | |
|--|-----|
| 2. 12:24:20 time-02.txt → new create | Yes |
| 8. 12:29:50 time-02.txt → open/access file | No |
| 9. 12:30:01 time-02.txt → close | No |

time-03.txt, time-03 - Copy.txt

- | | |
|---|--------|
| 3. 12:25:24 time-03.txt → new create | Yes |
| 10. 13:07:52 time-03.txt → copy to time-0003 - Copy.txt | Yes/No |

time-44.txt

- | | |
|--|--------|
| 4. 12:26:05 time-04.txt → new create | Yes |
| 11. 13:10:36 time-04.txt → rename to time-0044.txt | Yes/No |

time-05.txt

- | | |
|--|-----|
| 5. 12:27:00 time-05.txt → new create | Yes |
| 14. 13:58:07 time-05.txt → delete file | No |

time-06.txt

- | | |
|---|--------|
| 12. 13:14:20 time-06.txt → new created on other drive | Yes/No |
| 13. 13:56:30 time-06.txt → copy to local drive | Yes |

5.5 Create a Time Line

```
$ mkdir time
```

```
$ fls -f ntfs -o 2048 -m D:/ -r ntfs.raw > time/d.body
```

```
-m      Time machine format
D:/     Add D:/ as mountpoint in report
-r      Recursive
```

```
$ cd time
```

```
$ mactime -b d.body > d.time
```

```
$ less d.time
```

```
.....
Mon Dec 02 2019 16:25:22      15000 .a.b      73-128-2 D:/small_text_file.txt (deleted)
Wed Dec 04 2019 14:41:27      15051 .a.b      64-128-2 D:/AaaA.txt
Wed Dec 04 2019 14:42:06      15051 m.c..    64-128-2 D:/AaaA.txt
Wed Dec 04 2019 14:43:20      15000 macb     65-128-2 D:/Nonresident.txt (deleted)
Thu Dec 05 2019 12:10:53      24064 m.cb     66-128-2 D:/6-cluster.txt
Thu Dec 05 2019 12:11:12      24064 .a..     66-128-2 D:/6-cluster.txt
Mon Dec 09 2019 14:37:09         168 ...b     72-144-2 D:/NTFS_Sub_Dir
Mon Dec 09 2019 14:38:08         168 m.c..    72-144-2 D:/NTFS_Sub_Dir
                               13 macb     74-128-2 D:/NTFS_Sub_Dir/sub_Dir_File1.txt
Mon Dec 09 2019 14:38:24         168 .a..     72-144-2 D:/NTFS_Sub_Dir
Mon Dec 09 2019 16:09:46      15000 m.c..    73-128-2 D:/small_text_file.txt (deleted)
Sun Nov 29 2076 09:54:34      76800 macb     0-128-1 D:/SMFT
```



6.



7. Carving and String Search

7.1 Magic Bytes - File signatures

```
xxd logo_h4k-350x250.jpg | less
00000000: ffd8 ffe0 0010 4a46 4946 0001 0100 0001  .... JFIF .....
...
...
0008cc0: 0fa5 0a28 141a 0028 a0d0 3a50 07ff d9    ... ( ... ( ... P ...
```

```
xxd cases.jpg | less
00000000: ffd8 ffe1 0018 4578 6966 0000 4949 2a00  .... Exif .. II *.
...
...
0001730: 4028 0500 a014 0280 501f ffd9             @ ( ..... P ...
```

/etc/scalpel/scalpel.conf

jpg	y	200000000	\xff\xd8\xff\xe0\x00\x10	\xff\xd9
jpg	y	200000000	\xff\xd8\xff\xe1	\xff\xd9

7.1 Magic Bytes - File signatures

```
xxd MECO-SMILE.pdf | less
00000000: 2550 4446 2d31 2e34 0a25 c7ec 8fa2 0a35  %PDF-1.4.%.....5
...
...
005c4d0: 3431 390a 2525 454f 460a                419.%%EOF.
```

```
xxd LU-NCSS-2-EN.pdf | less
00000000: 2550 4446 2d31 2e35 0d25 e2e3 cfd3 0d0a  %PDF-1.5.%.....
...
...
0007a7e0: 6566 0d31 3136 0d25 2545 4f46 0d        ef.116.%%EOF.
```

/etc/scalpel/scalpel.conf

pdf	y	5000000	%PDF	%EOF\x0d	REVERSE
pdf	y	5000000	%PDF	%EOF\x0a	REVERSE

7.2 Carving tools

- Foremost
 - Version 1.5.7
- Scalpel
 - Version 1.60
 - Based on Foremost 0.69
- Bulk Extractor
 - Emails, Email addresses
 - URLs
 - Credit card numbers
 - Social media
 - Telephone numbers
 - ...
- Testdisk - Photorec

7.3 Limitations

- Basically file system independent
- Data sequential
 - Data must be sequential
 - Fragmented data leads to broken files
 - Very large files are more fragmented
 - Depends on file system
 - Depends on media type
 - Data could be overwritten partially
- End of file
 - Does the file format support end marker
 - Do we find a new magic byte
 - Overlapping files
 - Empty space at the end of a sector

7.4 Exercise: Recover data from formatted drive

- Try meta data based recovery with `fls`
- Carving formatted drive

```
mkdir out1/  
foremost -t all -i formatted.dd -o out1/  
  
out1/audit.txt
```

```
File: deleted.dd  
Start: Wed Aug 22 16:20:43 2018  
Length: 32 MB (33554432 bytes)
```

Num	Name (bs=512)	Size	File Offset	Comment
0:	00009032.jpg	5 KB	4624384	
1:	00009080.jpg	35 KB	4648960	
2:	00037617.jpg	30 KB	19260232	
3:	00037678.jpg	106 KB	19291633	
.....				
16:	00037608.pdf	1 MB	19255296	
17:	00041288.pdf	489 KB	21139456	(PDF is Linearized)
Finish: Wed Aug 22 16:20:43 2018				
18 FILES EXTRACTED				
jpg:= 9				
png:= 6				
pdf:= 3				

7.5 What is 'String Search'?

- Not sophisticated
- Search for strings
 - At least 4 characters long
 - From any file: Text, binary, disk image
 - Search for ASCII, Unicode, big/little endian
- Search the disk image for known words
 - Terms used in a secret document
 - IBAN or other banking details
 - Email addresses or URLs
- Search through all the blocks
 - Allocated non-slocated blocks
 - File slack and outside partition boundaries
- Goal
 - Proof that the data was there once
 - Identify interesting data that are close

7.6 Examples

- Search for strings
 - `strings -a circl-dfir.dd | less`
- Min-Len
 - `strings -a -n 10 circl-dfir.dd | less`
- Unicode 16 bit little endian
 - `strings -a -n 10 -el circl-dfir.dd | less`
- Unicode 16 bit big endian
 - `strings -a -n 10 -eb circl-dfir.dd | less`
- Offset in decimal
 - `strings -a -n 10 -eb -td circl-dfir.dd | less`
- `grep` for your search term
 - `strings -a -n 10 -td circl-dfir.dd | grep -i paula`

7.7 Steps to do a String Search

1. Identify block/cluster size
`mmls, fsstat`
2. Search for the string and the offset
`blkls | srch_strings | grep`
3. Calculate block/cluster of the string
`xxxxxxxxxx / 4096 = yyyy`
4. Review block/cluster content
`blkcat`
5. Identify inode of the block/cluster
`ifind`
6. Identify associated file
`ffind`
7. Recover file
`icat`
Or mount and copy file

7.8 Exercise: What about Paulas cat?

1. Identify cluster size

```
mmls circl-dfir.dd
```

1	Slot	Start	End	Length	Description
000:	Meta	0000000000	0000000000	0000000001	Primary Table (#0)
001:	_____	0000000000	0000002047	0000002048	Unallocated
002:	000:000	0000002048	0004917247	0004915200	NTFS / exFAT (0x07)

```
fsstat -o 2048 circl-dfir.dd
```

```
File System Type: NTFS
Volume Serial Number: 7B6E5F9427919882
OEM Name: NTFS
Volume Name: CIRCL-DFIR
Version: Windows XP
```

```
.....
```

```
Sector Size: 512
Cluster Size: 4096
Total Cluster Range: 0 — 614398
Total Sector Range: 0 — 4915198
```

7.8 Exercise: What about Paulas cat?

2. Search for the string 'Paula'

```
blkls -e -o 2048 circl-dfir.dd | strings -a -td | grep -i paula

157342 Paula's cat is fat .....
157370 Paula's cat is fat .....
.....
157510 Paula's cat is fat .....
157538 Paula's cat is fat .....
```

3. Calculate cluster of the string

```
echo $((157342/4096))
38
```

```
echo $((157538/4096))
38
```

4. Review cluster content

```
blkcat -o 2048 circl-dfir2dd 38 | strings

.....
Paula's cat is fat .....
Paula's cat is fat .....
Paula's cat is fat .....
.....
```

7.8 Exercise: What about Paulas cat?

5. Identify inode of the cluster

```
ifind -o 2048 -d 38 circl-dfir.dd  
0-128-1
```

6. Identify associated file

```
ffind -o 2048 circl-dfir.dd 0-128-1  
//$MFT
```

7. Recover file

```
icat -o 2048 circl-dfir.dd 0-128-1 > MFT
```

Exercise: Manual approach - Learn from errors

```
dd if=circl-dfir.dd bs=4096 skip=38 count=1 | xxd | less  
dd if=circl-dfir.dd bs=4096 skip=$((2048 + 38)) count=1 | xxd | less  
dd if=circl-dfir.dd bs=4096 skip=$((2048/8 + 38)) count=1 | xxd | less
```



8. Forensics Challenges

8.1 NTFS - Resident file becomes Non-Resident

- Situation:
 - NTFS formatted partition
 - A small resident file
- Challenge:
 - Analyze MFT record
 - Let the file grow
 - Analyze MFT record
 - Analyze data clusters
 - Modify content of the file
 - Analyze data clusters
 - Analyze MFT record

8.1 NTFS - Resident file becomes Non-Resident

```
$ ls -l /cdrom/NTFS_Sub_Dir/sub_Dir_File1.txt
13 Dez  9 14:38 /cdrom/NTFS_Sub_Dir/sub_Dir_File1.txt

$ fls -r -o 2048 ntfs.raw | grep File1
+ r/r 74-128-2:      sub_Dir_File1.txt

$ istat -o 2048 ntfs.raw 74
Attributes:
Type: $DATA (128-2)   Name: N/A   Resident   size: 13

$ dd if=ntfs.raw skip=$((2048 + 4*8 + 74*2)) count=2 | xxd | less
00000000: 4649 4c45 3000 0300 0000 0000 0000 0000  FILE0 .....
00000010: 0100 0100 3800 0100 9801 0000 0004 0000  ....8.....
.....
00000170: 0000 0000 0000 0200 0d00 0000 1800 0000  .....
00000180: 4865 6c6c 6f20 576f 726c 6421 0a00 0000  Hello World!....
00000190: ffff ffff 0000 0000 0000 0000 0000 0000  .....

$ for x in {1..1000}; do echo -n "$x "; done >> /cdrom/NTFS_Sub_Dir/sub_Dir_File1.txt

$ less /cdrom/NTFS_Sub_Dir/sub_Dir_File1.txt
Hello World!
 1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21
.....
```

8.1 NTFS - Resident file becomes Non-Resident

```
$ ls -l /cdrom/NTFS_Sub_Dir/sub_Dir_File1.txt
3906 Apr 24 14:39 /cdrom/NTFS_Sub_Dir/sub_Dir_File1.txt

$ fls -r -o 2048 ntfs.raw | grep File1
+ r/r 74-128-2:      sub_Dir_File1.txt

$ istat -o 2048 ntfs.raw 74
Attributes:
Type: $DATA (128-2)   Name: N/A   Non-Resident   size: 3906   init_size: 3906
4173

$ dd if=ntfs.raw skip=$((2048 + 4173*8)) count=8 | xxd | less
00000000: 4865 6c6c 6f20 576f 726c 6421 0a31 2032   Hello World!.1 2
00000010: 2033 2034 2035 2036 2037 2038 2039 2031   3 4 5 6 7 8 9 1
00000020: 3020 3131 2031 3220 3133 2031 3420 3135   0 11 12 13 14 15
.....

$ dd if=ntfs.raw skip=$((2048 + 4*8 + 74*2)) count=2 | xxd | less
000001a0: 420f 0000 0000 0000 2101 4d10 0020 3135   B.....!.M.. 15
000001b0: ffff ffff 0000 0000 3820 3139 2032 3020   .....8 19 20
000001c0: 3231 2032 3220 3233 2032 3420 3235 2032   21 22 23 24 25 2
.....
000003e0: 2031 3737 2031 3738 2031 3739 2031 3830   177 178 179 180
000003f0: 2031 3831 2000 0000 ffff ffff 0000 d607   181 .....
```

8.1 NTFS - Resident file becomes Non-Resident

Update file content: What happen with MFT Record?

```
$ echo -n 'We modify the content of the file. What is updated:
Cluster? MFT Record? We will see.' | dd of=/cdrom/
NTFS_Sub_Dir/sub_Dir_File1.txt bs=44 seek=2 conv=notrunc

$ fls -r -o 2048 ntfs.raw | grep File1
+ r/r 74-128-2:      sub_Dir_File1.txt

$ istat -o 2048 ntfs.raw 74
4173

$ dd if=ntfs.raw skip=$((2048 + 4173*8)) count=8 | xxd | less
00000040: 3231 2032 3220 3233 2032 3420 3235 2032 21 22 23 24 25 2
00000050: 3620 3237 2032 3820 5765 206d 6f64 6966 6 27 28 We modif
00000060: 7920 7468 6520 636f 6e74 656e 7420 6f66 y the content of
.....

$ dd if=ntfs.raw skip=$((2048 + 4*8 + 74*2)) count=2 | xxd | less
000001c0: 3231 2032 3220 3233 2032 3420 3235 2032 21 22 23 24 25 2
000001d0: 3620 3237 2032 3820 3239 2033 3020 3331 6 27 28 29 30 31
000001e0: 2033 3220 3333 2033 3420 3335 2033 3620 32 33 34 35 36
.....
```


8.2 File System Tunneling

- Situation:
 - NTFS formatted partition
 - A normal file from before
- Challenge:
 - Analyze timestamps
 - Delete the file
 - Copy a file with the same filename
 - Analyze timestamps
 - Discover the behavior

8.2 File System Tunneling

1. Analyze time stamps of a file on NTFS

```
$ ll /cdrom/AaaA.txt
15051 Dez  4 14:42 /cdrom/AaaA.txt*

$ fls -o 2048 ntfs.raw | grep AaaA
r/r 64-128-2:      AaaA.txt

$ istat -o 2048 ntfs.raw 64

$STANDARD_INFORMATION Attribute Values:
Created:          2019-12-04 14:41:27.333050500 (CET)
File Modified:    2019-12-04 14:42:06.235661600 (CET)
MFT Modified:     2019-12-04 14:42:06.235661600 (CET)
Accessed:         2019-12-04 14:41:27.333050500 (CET)

$FILE_NAME Attribute Values:
Created:          2019-12-04 14:41:27.333050500 (CET)
File Modified:    2019-12-04 14:41:27.333050500 (CET)
MFT Modified:     2019-12-04 14:41:27.333050500 (CET)
Accessed:         2019-12-04 14:41:27.333050500 (CET)
```

2. Delete a file and create a new one with same filename

```
# Do something like this on a Windows PC
$ rm /cdrom/AaaA.txt; cp data_un.dd /cdrom/AaaA.txt
```

8.2 File System Tunneling

3. Analyze time stamps of the new file

```
$ ll /cdrom/AaaA.txt
16384 Apr 27 15:51 /cdrom/AaaA.txt*
```

```
$ fls -o 2048 ntfs.raw | grep AaaA
r/r 64-128-2:      AaaA.txt
```

```
$ istat -o 2048 ntfs.raw 64
```

```
$STANDARD_INFORMATION Attribute Values:
```

```
Created:          2019-12-04 14:41:27.333050500 (CET)
File Modified:    2019-12-04 14:42:06.235661600 (CET)
MFT Modified:     2019-12-04 14:42:06.235661600 (CET)
Accessed:         2020-04-27 16:11:38.144645700 (CEST)
```

```
$FILE_NAME Attribute Values:
```

```
Created:          2019-12-04 14:41:27.333050500 (CET)
File Modified:    2019-12-04 14:41:27.333050500 (CET)
MFT Modified:     2019-12-04 14:41:27.333050500 (CET)
Accessed:         2019-12-04 14:41:27.333050500 (CET)
```

.....

8.3 Un-Delete a file

- Situation:
 - NTFS formatted partition
 - A file is deleted
- Challenge:
 - Analyze MFT record before delete
 - Analyze \$BITMAP file before delete
 - Undo the modifications
 - Analyze MFT record after undo
 - Analyze \$BITMAP file after undo
 - What is missing

8.3 Un-Delete a file

```
$ ls -l /cdrom/
```

```
$ fls -o 2048 ntfs.raw  
-/r * 73-128-2:      small_text_file.txt
```

```
$ istat -o 2048 ntfs.raw 73  
Type: $DATA (128-2)   Name: N/A   Non-Resident   size: 15000   init_size: 15000  
4169 4170 4171 4172
```

Data cluster:

```
$ dd if=ntfs.raw skip=$((2048 + 4169*8)) count=$((4*8)) | xxd | less
```

MFT record 73:

```
$ dd if=ntfs.raw skip=$((2048 + 4*8 + 73*2)) count=2 | xxd | less
```

\$Bitmap file

```
4169 / 8 = 521.125  —> Byte 521 (0x209) in $Bitmap file for Cluster 4168 — 4175  
                    —> - - - - -  
                        x  x x x
```

```
$ icat -o 2048 ntfs.raw 6 | xxd | less
```

8.3 Un-Delete a file

Fix \$Bitmap file:

```
$ istat -o 2048 ntfs.raw 6
  Type: $DATA (128-1)   Name: N/A   Non-Resident   size: 4064   init_size: 4064
  4071
```

```
$ dd if=ntfs.raw skip=$((2048 + 4071*8)) count=8 | xxd | less
00000200: ffff ffff ffff ffff ffe1 0700 0000 0000  ....
```

```
4169 / 8 = 521.125  -> Byte 521 (0x209) in $Bitmap file for Cluster 4168 - 4175
-> - - - - -
      x x x x
    1 1 1 0  0 0 0 1
-> 1 1 1 1  1 1 1 1
```

```
$ dd if=ntfs.raw skip=$((2048 + 4071*8)) count=8 of=bitmap.dd
$ hexedit of=bitmap.dd
$ dd if=bitmap.dd seek=$((2048 + 4071*8)) of=ntfs.raw conv=notrunc
```

```
$ dd if=ntfs.raw skip=$((2048 + 4071*8)) count=8 | xxd | less
00000200: ffff ffff ffff ffff ffff 0700 0000 0000  ....
```

8.3 Un-Delete a file

Fix the MFT record:

```
$ dd if=ntfs.raw skip=$((2048 + 4*8 + 73*2)) count=2 of=mft_73.dd
```

```
$ hexedit mft_73.dd
```

```
00000000  46 49 4C 45 30 00 03 00 00 00 00 00 00 00 00 00  FILE0.....
00000010  02 00 00 00 38 00 00 00 B8 01 00 00 00 04 00 00  ....8.....
```

offset:	size:	old value:	new value:	description:
0010	2	2	1	Record sequence number
0012	2	0	1	Link count
0016	2	0	1	Record flag: 0000 = file deleted 0100 = file in use
0030	2	1400		FixUp values
03fe	2	1400		CRC


```
00000000  46 49 4C 45 30 00 03 00 00 00 00 00 00 00 00 00  FILE0.....
00000010  01 00 01 00 38 00 01 00 B8 01 00 00 00 04 00 00  ....8.....
```

```
$ dd if=mft_73.dd seek=$((2048 + 4*8 + 73*2)) count=2 of=ntfs.raw conv=notrunc
```

8.3 Un-Delete a file

- What is missing?
 - Compare output `ils` and `fls`
 - What about the directory
 - What is changed in a directory if a file is deleted?

→ Forensics Hackathon



10. Bibliography and Outlook

10. Bibliography

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10. Outlook

CIRCL DFIR 1.0.2

EXT File System

Overview

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2. FAT - File Allocation Table
3. NTFS - New Technology File System
4. NTFS - Advanced
5. File System Time Line
6. Carving
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