CIRCL - DFIR 1.0.2

Introduction: File System Forensics and Data Recovery

CIRCL *TLP:WHITE*

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Thanks to:

AusCERT

JISC

Overview

1. File System Analysis - Overview
2. FAT - File Allocation Table
3. NTFS - New Technology File System
4. NTFS - Advanced
5. File System Time Line
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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

    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

```
   ----------------------------------------------------------------------------
   +    +    +    |    +    +    +    |    +    +    +    |    +    +    +    |
   ----------------------------------------------------------------------------

                  |                   |                   |                   |
                  |                   |                   |                   |

                  -------------------------------------------------------------
                  |....+....+....+....|....+..00+????+????|                   |
                  -------------------------------------------------------------
                            1                   1                   0

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 cluter: 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
fcat          # 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 unallocted 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
```

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2. FAT - File Allocation Table

2.1 FAT file system structure

- 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 or 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 --> 0x0200 =  512 Bytes
13 (0x0D)    1        Sectors/Cluster    0x04               = 2048 Bytes
14 (0x0E)    2        Sector before FS   0x0400 --> 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 or 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 --> 0x0200 =  512 Bytes
13 (0x0D)   1        Sectors/Cluster    0x04               = 2048 Bytes
14 (0x0E)   2        Sector before FS   0x0400 --> 0x0004 =     4 Sectors
16 (0x10)   1        Copies of FAT      0x02
.....
```

2.2 FAT components simplified

```
Root Directory:                        |     Content of file:
                                       |
   Name     Ext     Start   Size       |     Not part of Root directory
  ______________________________       |    ______________________________
    file_A   txt        3     28       |     aaaaaaaaaaaaaaaaaaaaaaaaaaaa
    file_B   txt        7      4       |     bbbb
         .....

Data Clusters: (Size of 8 characters)
   _________________________________________________________________________
   |        |aaaaaaaa|aaaaaaaa|aaaaaaaa|        |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
     .....AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA.....

file02.txt
     .....XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.....
```

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 Byes      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 (0×00)   11       File Name         .ILE01  TXT
     .....
     26 (0×1A)    2       Low Cluster       0×0300 —> 03
     28 (0×1C)    4       Size in Byes      0×8813 —> 0×1388 == 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 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 Byes      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 Byes      0x25000000 —> 0x25 == 37


Data Clusters:

     dd if=FAT/fat16.dd skip=172 count=4 | xxd | less     1234567890ABCDEF
                                                           ................
                                                          AAAAAAAAAAAAAAAA
                                                          AAAAAAAAAAAAAAAA
     dd if=FAT/fat16.dd skip=176 count=4 | xxd | less     AAAAAAAA........


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

- Prepararation:

```
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  OOOOOOOOOOOOOOOO

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  OOOOOOOOOOOOOOOO
```

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3. NTFS - New Technology File System

3.1 NTFS file system structure

```
______________________________
|    Volume Boot Record      |     — Similar to FAT
______________________________
|    Master File Table       |     — MFT, ~12.5\% of volume
______________________________
|                            |
|                            |
|       Data Clusters        |
|                            |
|                            |
______________________________
|                            |
|        MFT Mirror          |     — First 4 MFT entries
|                            |
______________________________
|                            |
|                            |
|       Data Clusters        |
|                            |
|                            |
______________________________
|    Backup Boot Record      |
______________________________
```

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 —> 2^10 = 1.024
00000054	426		Bootstrap code
000001FE	2	55 AA	End of sctor 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 lable, version
4	$AttrDef	Attribute definitions
5		Root Directory
6	$Bitmap	Allocation status for each cluster
7	$Boot	Boot Sector and boot code
8	$BadClus	Bas 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 Record: 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

     AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
     AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
     .....
```

```
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  AAAAAAAAAAAAAAAA
     0010: 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAA
     .....
```

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:\text.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 suported 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

CIRCL FORENSICS Training

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       0      $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_INOFRMATION
   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 lenght
0172	2	0000	0	Name offset
0174	2	0000	0	Flags
0176	2	0200	2	Attribute ID
0178	4	0d00 0000	13	Attribute lenght
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                       # 12 * 8 = 96
          —> Allocated Cluster: 96, 102, 103
          —> Not allocated Clusters: 97, 98, 99, 100. 101


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  AAAAAAAAAAAAAAAA
00000010: 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAA
.....
00003a70: 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAA
00003a80: 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAA
00003a90: 4141 4141 4141 4141 0000 0000 0000 0000  AAAAAAAA........
00003aa0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
00003ab0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
.....
00003fe0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
00003ff0: 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  AAAAAAAAAAAAAAAA
00000010: 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAA
.....
00003a70: 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAA
00003a80: 4141 4141 4141 4141 4141 4141 4141 4141  AAAAAAAAAAAAAAAA
00003a90: 4141 4141 4141 4141 0000 0000 0000 0000  AAAAAAAA........
00003aa0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
00003ab0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
.....
00003fe0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
00003ff0: 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=$((2048 + 4*8 + 72*2)) count=2 | xxd | less
    00000080: 3000 0000 7800 0000 0000 0000 0000 0300  0...x...........
    .....
    000000d0: 2000 0010 0000 0000 0c00 4e00 5400 4600   .........N.T.F.
    000000e0: 5300 5f00 5300 7500 6200 5f00 4400 6900  S._.S.u.b._.D.i.
    000000f0: 7200 1800 0000 0200 5000 0000 6800 0000  r.......P...h...
    .....
    00000160: 9000 0000 c800 0000 0004 1800 0000 0200  ................
    00000170: a800 0000 2000 0000 2400 4900 3300 3000  .... ...$.I.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

CIRCL
FORENSICS Training

5. File System Time Line

5.1 Time stamps: Nomenclature

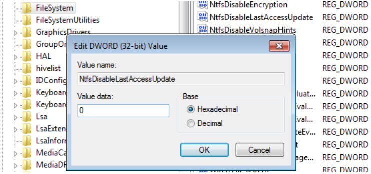
- FAT
  - MAC times
    - M time: Content last Modified
    - A time: Content last Accessed
    - C time: File Created
- NTFS
  - MACE times
    - M time: Content last Modified
    - A time: Content last Accessed
    - C time: File Created
    - E-time: MFT Entry last mofidied
  - MACB times
    - M 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 im memory, writen to disk after ≈1h
- As of Win Vista
  - Not updated per default
    - `HKEY_LOCAL_MACHINE/SYSTEM/CurrentControlSet/Control/ /FileSystem/NtfsDisableLastAccessUpdate`



NtfsDisableEncryption REG_DWORD

NtfsDisableLastAccessUpdate REG_DWORD

NtfsDisableVolsnapHints REG_DWORD

Edit DWORD (32-bit) Value

Value name: NtfsDisableLastAccessUpdate

Value data: 0

Base: ● Hexadecimal ○ Decimal

    - 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:/$MFT
```

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6.

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7. Carving and String Search

7.1 Magic Bytes - File signatures

```
xxd logo_h4k-350x250.jpg | less
0000000: ffd8 ffe0 0010 4a46 4946 0001 0100 0001  ......JFIF......
...
...
0008cc0: 0fa5 0a28 141a 0028 a0d0 3a50 07ff d9    ...(...(..:P...
```

```
xxd cases.jpg | less
0000000: 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
0000000: 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 formated drive

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

```
mkdir out1/
foremost -t all -i formated.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 ot other banking details
  - Email addresses or URLs
- Search thrue all the blocks
  - Allocated non sllocated blocks
  - File slack and outside partition boundaries
- Goal
  - Proof that the data was there once
  - Identify intresting 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
```

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8. Forensics Challenges

8.1 NTFS - Resident file becomes Non-Resident

- Situation:
  - NTFS formated 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 formated 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 formated 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?

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10. Bibliography and Outlook

10. Bibliography

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  ISBN-13: 978-1-59-749586-8

10. Bibliography

- File System Forensic Analysis

  Brian Carrier
  Pearson Education
  ISBN-13: 978-0-32-126817-4

- Forensic Computing: A Practitioner's Guide

  Anthony Sammes, Brian Jenkinson
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10. Outlook

CIRCL DFIR 1.0.2

- EXT File System

Overview

1. File System Analysis - Overview
2. FAT - File Allocation Table
3. NTFS - New Technology File System
4. NTFS - Advanced
5. File System Time Line
6. Carving
7. String Search
8. Forensics Challenges
9. Bibliography and Outlook