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CSN08101
Digital Forensics
Lecture 7: Disk Analysis and File System

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Objectives

- Investigative Process
  - Analysis Framework
- File Systems
  - FAT
  - NTFS
  - EXT3

} next week

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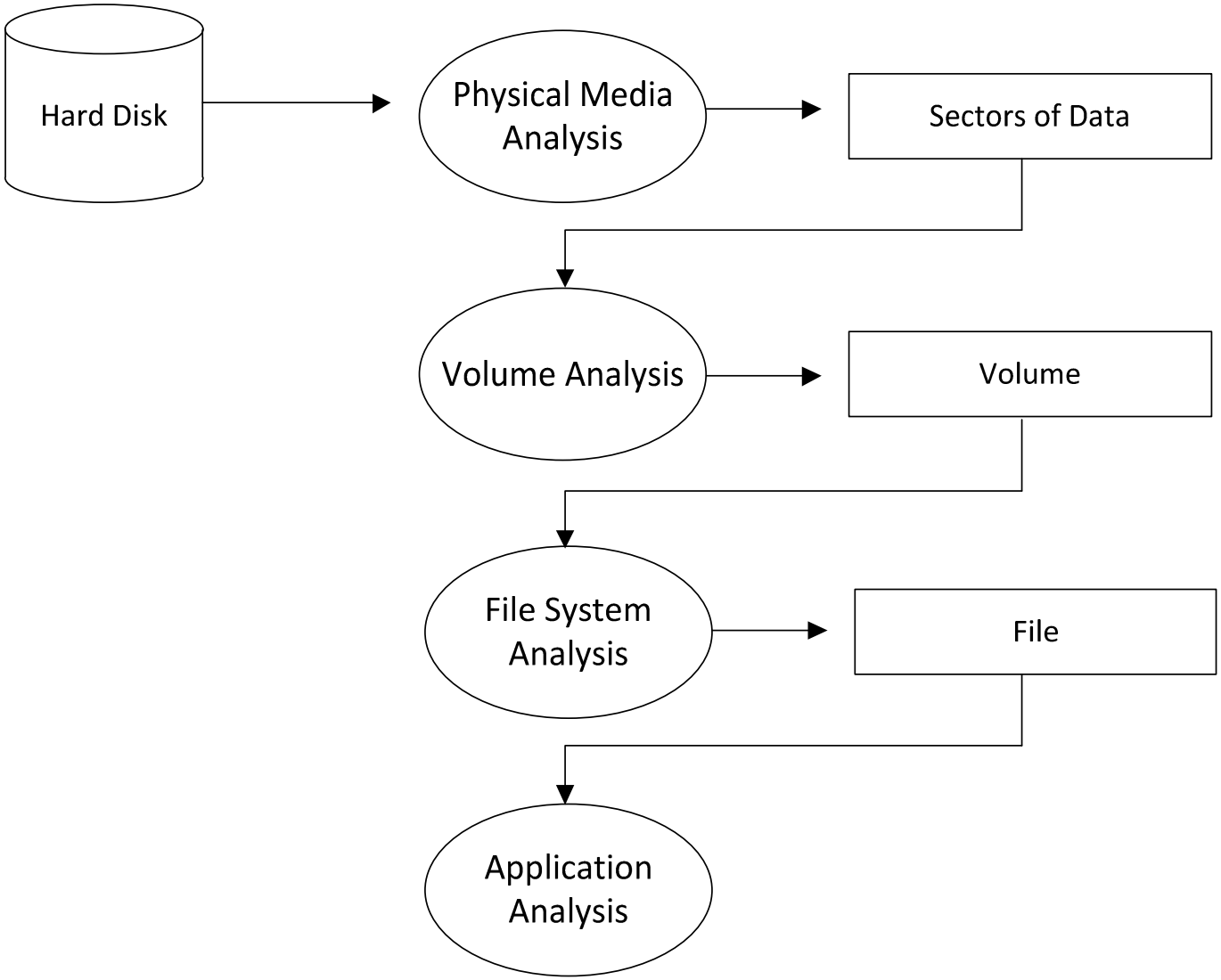
INVESTIGATIVE PROCESS

Investigative process



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Analysis Framework

- B Carrier, **File System Forensic Analysis**
- Data Categories provide a basic reference model
  - Good for comparing different file system types
  - Also allows us to understand how to search using various tool types

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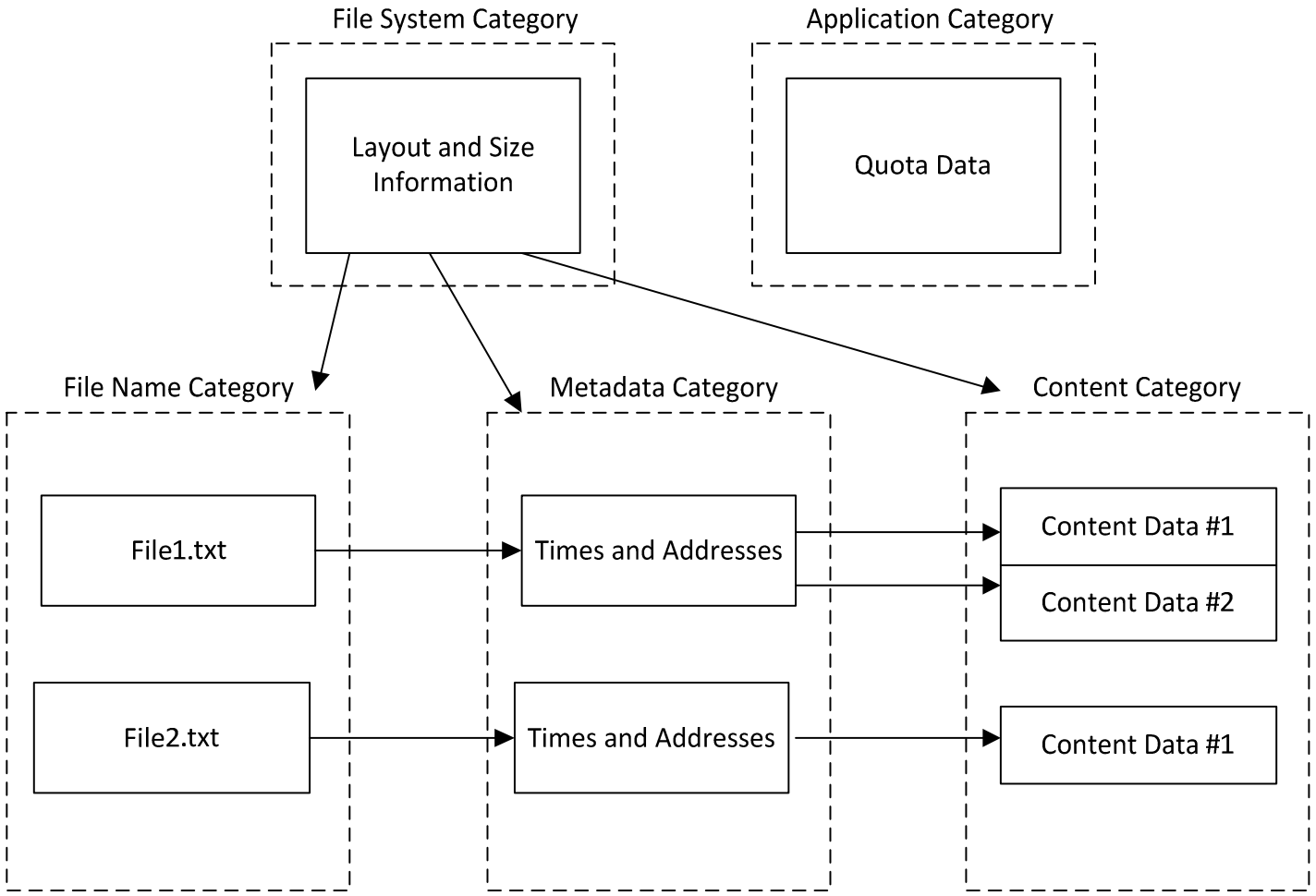
Categories

- File System Category
  - Content Category
  - Metadata Category
  - File Name Category
  - Application Category


File System Category
Application Category
Layout and Size Information
Quota Data
File Name Category
Metadata Category
Content Category
File1.txt
Times and Addresses
Content Data #1
Content Data #2
File2.txt
Times and Addresses
Content Data #1

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Analysis by Category

- Categories are important as they allow us to filter and search for files
- For example, if we want to search for all images
  - GIF, JPEG
  - Search for all files ending in .gif or .jpg, OR their file-header

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File System Category

- All file systems have a general structure
- Informs of where to find data structures
  - Think of this as a map
- File system data resides on the first few sectors of the disk
- If corrupted, rebuilding by hand may need to occur
- Small amounts of data hiding can occur due to the sparse usage of the pre-allocated data structures

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Disk and File System Layout

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Content Category

- Actual content of the file
- Contains the majority of the actual data
- Usually organised into standard-sized containers
  - Clusters
  - Data Unit
- Allocation Strategy
  - First Available
  - Next Available
  - Best Fit

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Analysis Techniques

- Data unit viewing
  - viewing content of the logical file system address using hex editor
  - `dcat`
- Logical file system-level searching
  - searches each data unit for know value
- Data unit Allocation Status
  - bitmap – data structure of allocated data units (marked as “1”) and unallocated data units (marked as “0”)

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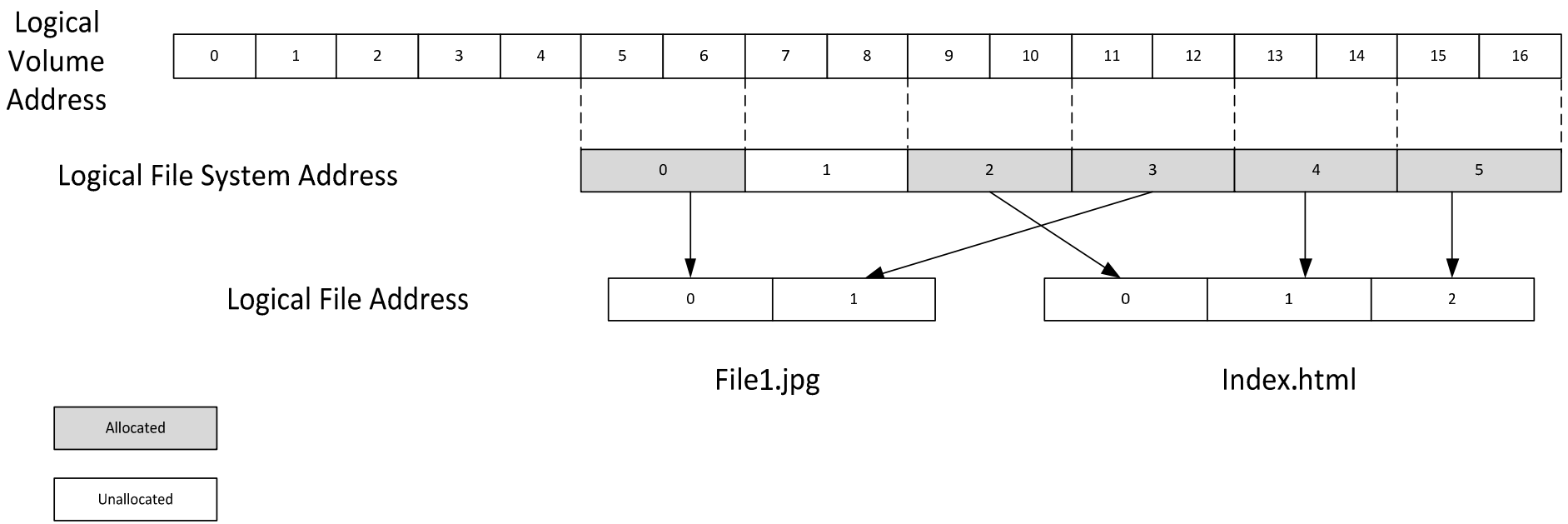
Metadata Category

- Where the descriptive data resides
  - Last access time
  - Data units allocated to the file
- Provides pointers to the address of the Logical File Address
- MAC times
  - Modification, Access, Change

File Addressing



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Analysis Techniques

- Metadata Lookup
  - `istat` – shows values from the metadata data structure

- Logical file viewing
  - `icat` - shows the content data for a given metadata structure

    -s option gives slack space

    -r attempts to recover deleted files

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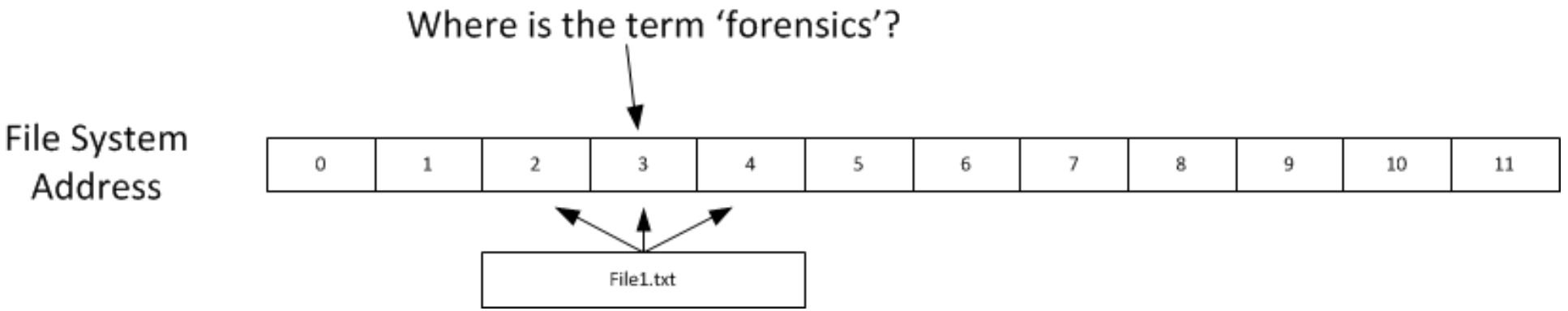
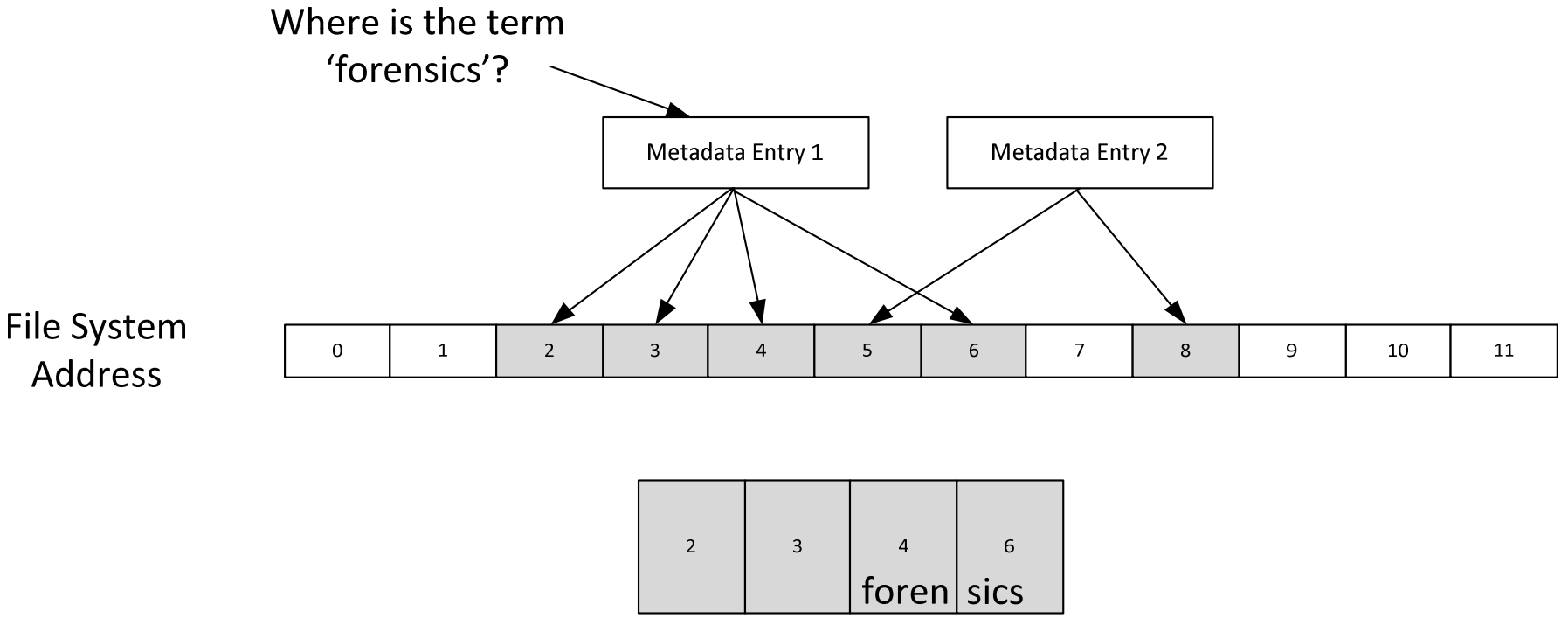
Linking Data Units to Files

- `ifind` allows you to discover the rest of the data units allocated to a file
- E.g. if we find something interesting in data unit 3, and want to look at the rest of the file



File Searching

- Logical File Search
  - Looks at the file-address level, takes into account fragmentation
  - Logical File Address allocated units only



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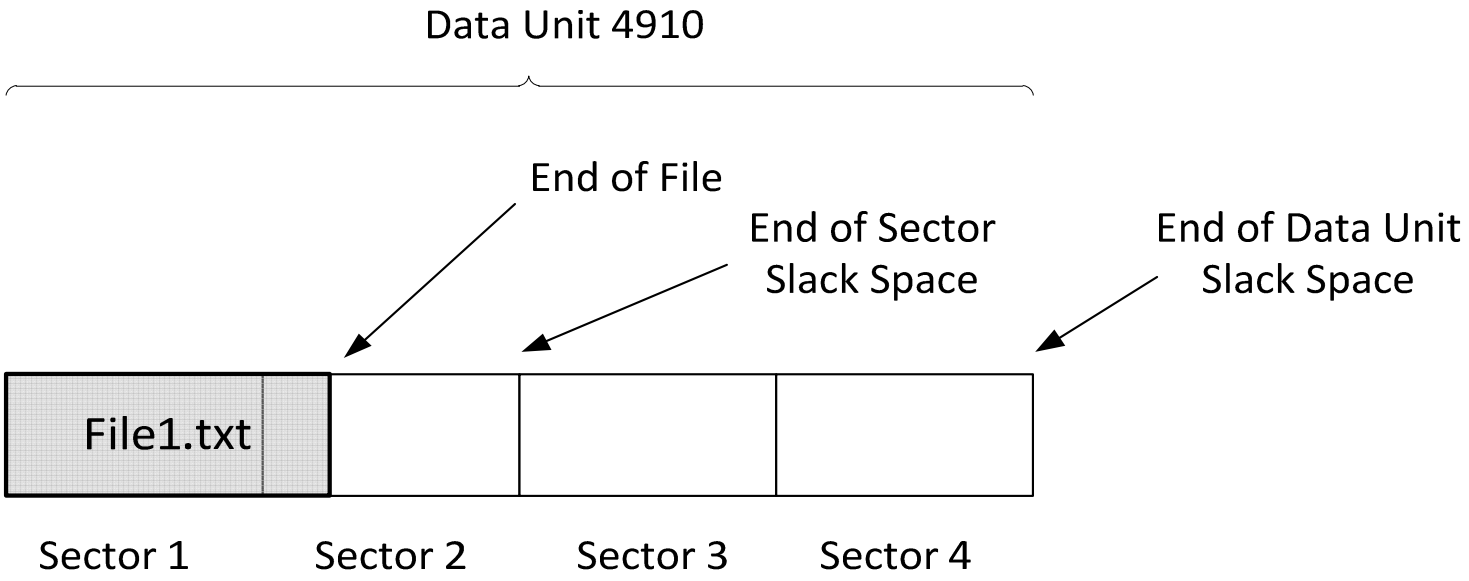
Slack Space

- Disks are block-based
- Example – File1.txt
  - 700 byte file
  - Needs to allocate full data unit (2,048 bytes)
  - The remaining 1,348 would be slack
- Two interesting areas:
  - Between end of file and end of sector
  - Allocated Data Unit Sectors that contain no file content


Data Unit 4910
End of File
End of Sector
Slack Space
End of Data Unit
Slack Space
File1.txt
Sector 1
Sector 2
Sector 3
Sector 4

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Unallocated Metadata

- File names may be deleted, but metadata may still exist
- Examine the metadata as this may contain evidence
- The tool *ils* will list unallocated structures

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Metadata Searching

- Allows time-based evaluation of activities
- Timelining events
- MAC
  - Modified
  - Access
  - Change
- Also owner ID and file permissions
- `mactime` tool in CAINE

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File Name Category

- Includes names of files
- Allows a user to find a file by name, instead of its metadata entry
- When recovering files based on file names
  - We are still reliant on the metadata information
  - File names and metadata can get out of sync

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File Name Analysis Techniques

- File Listings – locate root directory and obtain list of files and corresponding metadata addresses
- File Name Searching - file extension filtering and searching
  - `ffind -` resolve metadata to file names
  - When evidence in a data unit is found, search for the metadata unit allocated, search for file name

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Application Category

- Non-Essential Data – file system jurnals
- Can be application specific data
- Search
  - `grep`
  - Data carving
  - File type sorting
    - Use `file` command to determine file types based on file signatures

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FILE SYSTEMS

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File Systems

- An operating system requires long term storage and retrieval
- A mechanism for storing files in hierarchy of files and directories
  - For example, a patient record filing system

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File Systems

- Data
  - Files
  - Directories
- Metadata
  - Time stamps (modify, access, create/change, delete)
  - Owner
  - Security properties
- Structures
  - Superblock/Master File Table/File Access Table
  - inodes/clusters
  - data

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File Systems

- More sophisticated data recovery requires deep knowledge of file system internals
- Structures that manage file system metadata
- Disk layout
- File deletion issues
- Many important file systems
  - DOS / Windows: FAT, FAT16, FAT32, NTFS
  - Unix: ext2, ext3, Reiser, JFS
  - Mac: MFS, HFS, HFS+

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File Systems: FAT

- FAT12, FAT16, FAT32
  - different size of addressable cluseter
- Common format for floppy disks (remember those?)
- Limited time/date information for FAT files
  - Last write date/time is always available
  - Creation date/time is optional and may not be available
  - Last access DATE ONLY is optional and may not be available
- Short file names (8.3) on FAT12 and FAT16
- No security features
- Long names for FAT32

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FAT: Short Filename Storage

```
"foo.bar"       -> "FOO     BAR"
"FOO.BAR"       -> "FOO     BAR"
"Foo.Bar"       -> "FOO     BAR"
"foo"           -> "FOO        "
"foo."          -> "FOO        "
"PICKLE.A"      -> "PICKLE  A  "
"prettybg.big" -> "PRETTYBGBIG"
```

- Note case is not significant
- "." between primary filename and extension is implied (not actually stored)
- Further, everything is space-padded

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FAT: More Dir Entry Details

- Date format:
  - Bits 0–4: Day of month, valid value range 1-31 inclusive.
  - Bits 5–8: Month of year, 1 = January, valid value range 1–12 inclusive.
  - Bits 9–15: Count of years from 1980, valid value range 0–127 inclusive (1980–2107).
- Time Format:
  - A FAT directory entry time stamp is a 16-bit field that has a granularity of 2 seconds
  - Bits 0–4: 2-second count, valid value range 0–29 inclusive (0 – 58 seconds).
  - Bits 5–10: Minutes, valid value range 0–59 inclusive
  - Bits 11–15: Hours, valid value range 0–23 inclusive

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FAT: Long Filenames

- Summary: a kludge to add support without changing short-name handling
- Up to 255 characters in pathname component
- Total pathname no longer than 260
- More supported characters
- Leading/trailing spaces ignored
- Internal spaces allowed
- Leading/embedded “.” allowed
- Trailing “.” are ignored
- Stored case-sensitive
- Processed case-insensitive (for compatibility)
- File created with short name (uses “~1”, “~2”, etc. suffix)

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FAT Layout

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FAT File System Categories

	File System	Content	Metadata	File Name	Application
FAT	Boot Sector, FSINFO	Clusters, FAT	Directory Entries, FAT	Directory Entries	N/A

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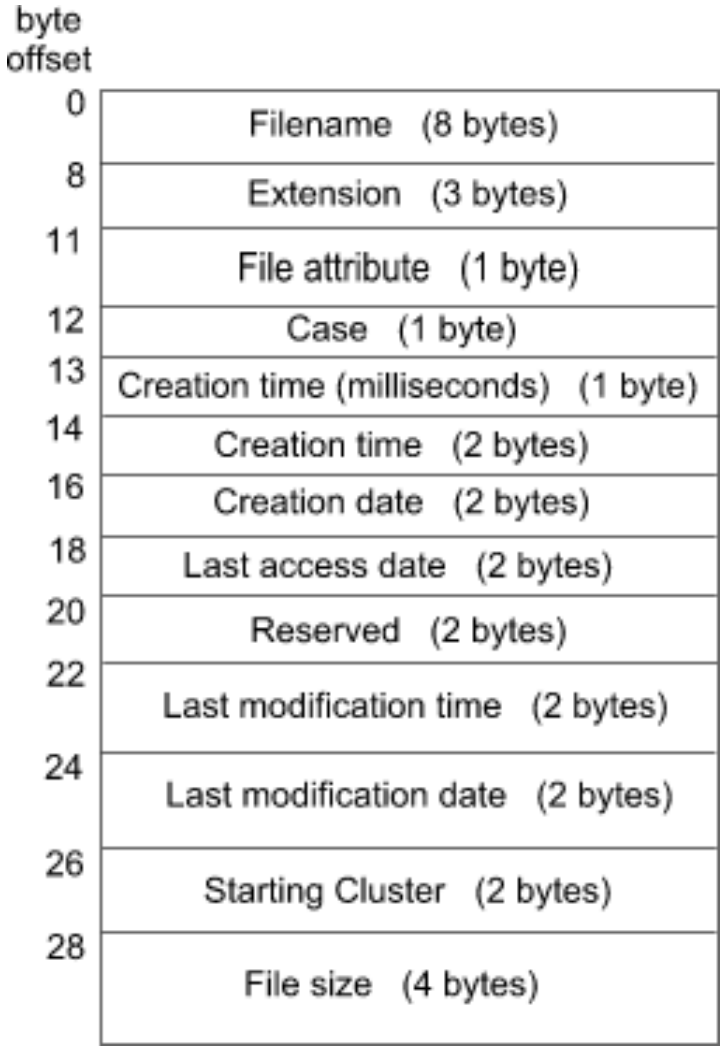
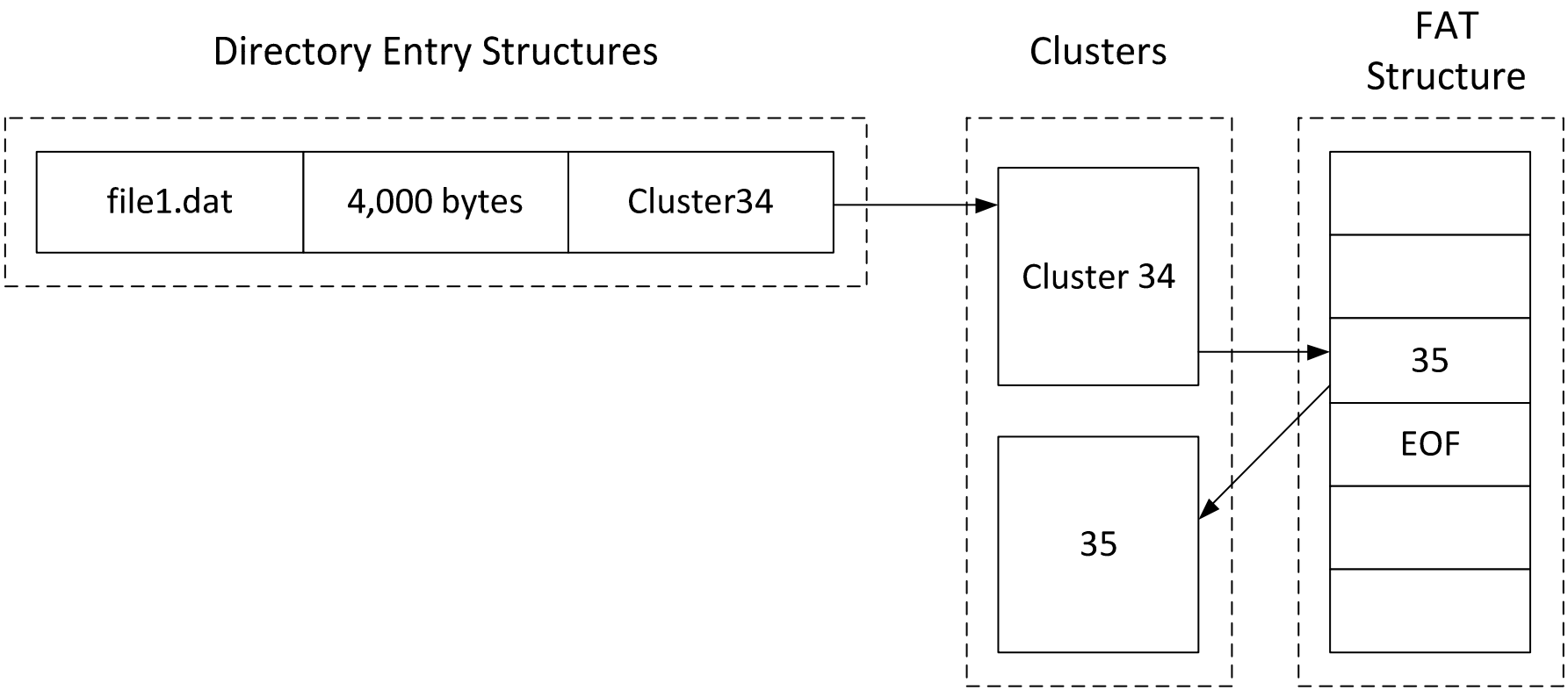
FAT32 Directory Structure

- An ordinary cluster chain
- Directory entry
  - 32 bytes for both files and directories
  - For deleted entries, first byte is set to 0xE5
  - First two entries in subdirectories are . and ..
  - Uses more than one entry to implement long filenames




Directory Entry Structures
Clusters
FAT Structure
file1.dat
4,000 bytes
Cluster34
Cluster 34
35
35
EOF

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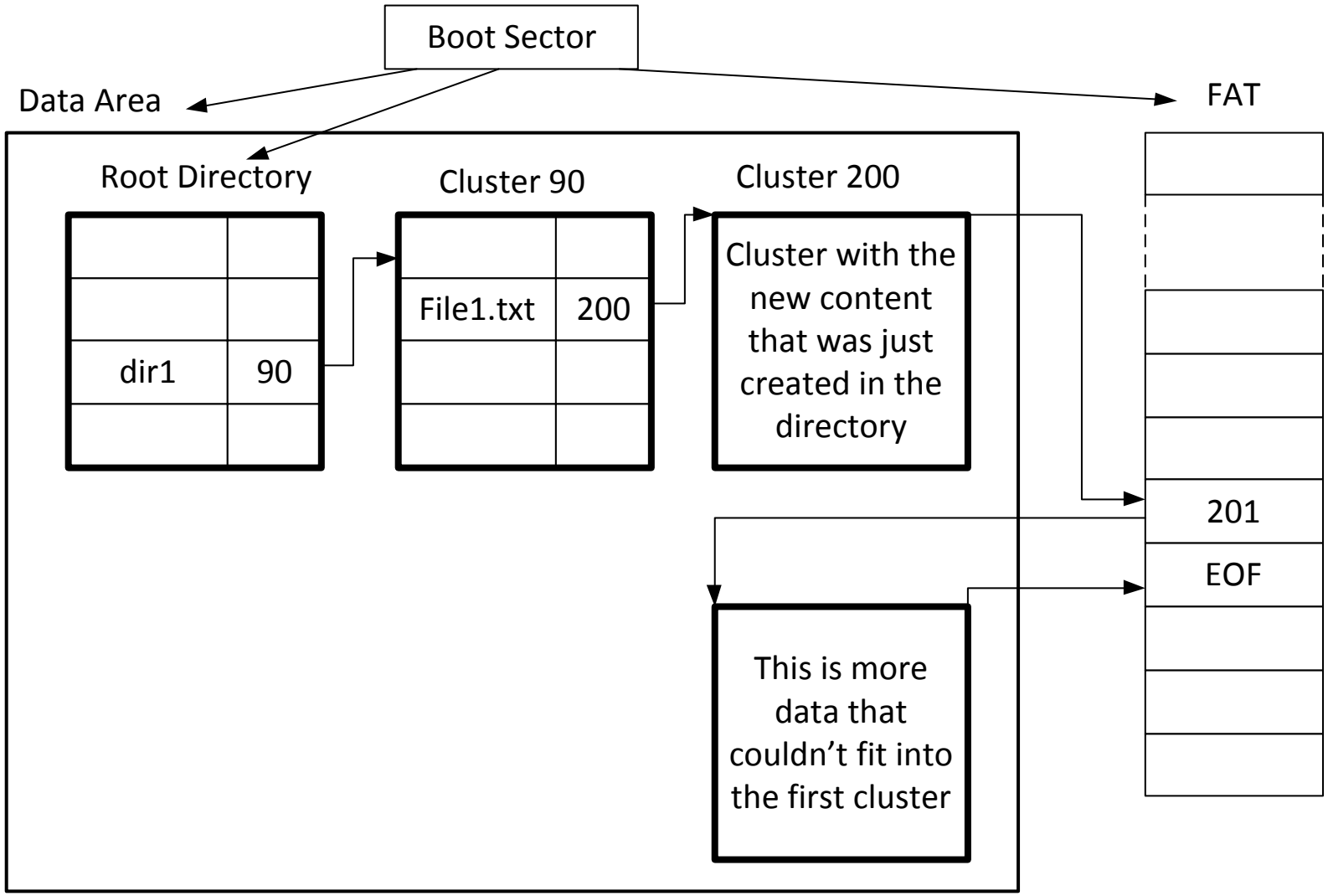
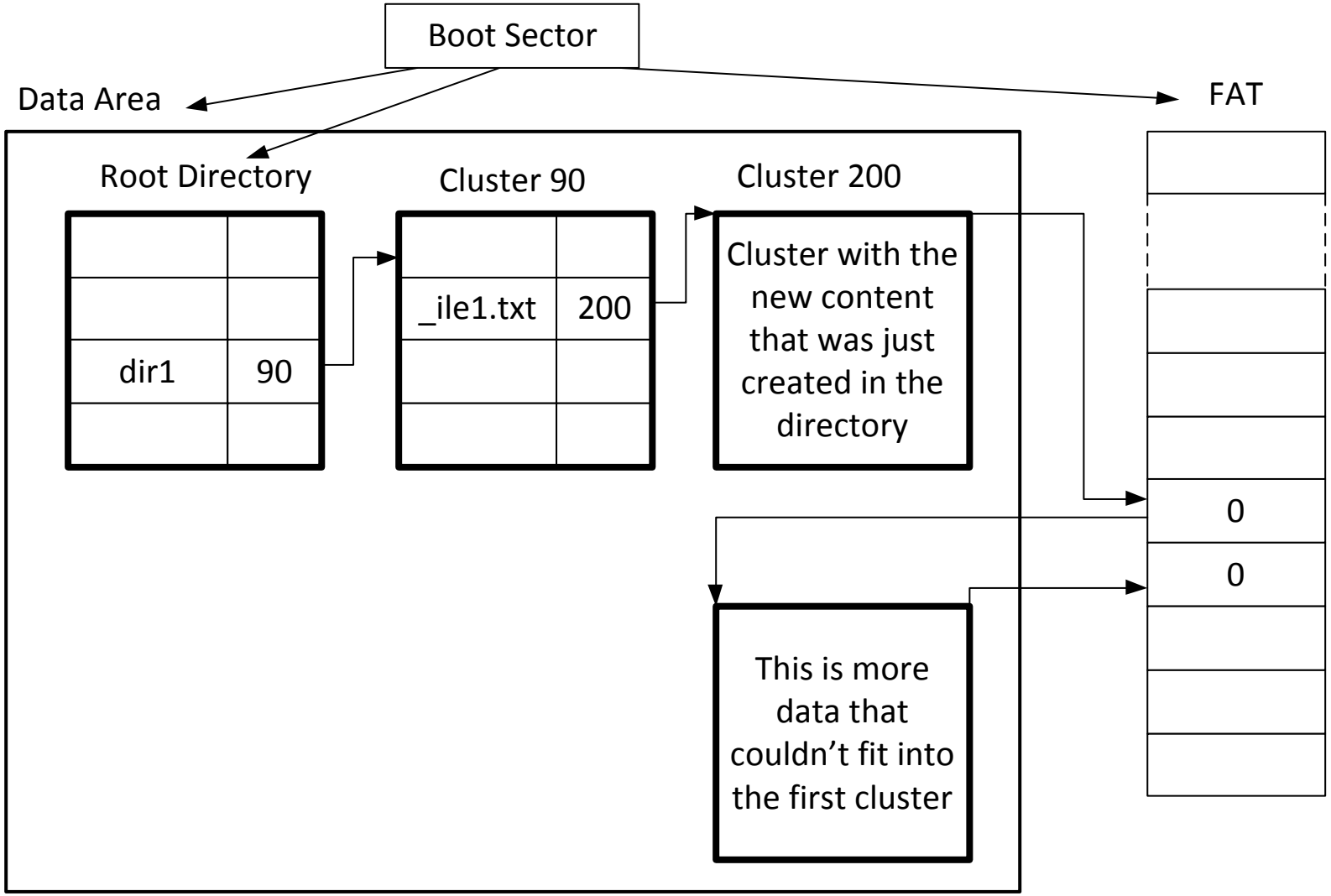
Creating a File



File Deletion



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FAT File Deletion

- First letter of the file is overwritten with 0xE5
- FAT pointers to allocation areas set to zero
  - Indicated that they are ready for re-use

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FORENSIC ANALYSIS - EXAMPLES

fsstat - display general details of a file system

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```
FILE SYSTEM INFORMATION
--------------------------------------------
File System Type: FAT16

OEM Name: MSDOS5.0
Volume ID: 0x3abd23ec
Volume Label (Boot Sector): NO NAME
Volume Label (Root Directory):
File System Type Label: FAT16

Sectors before file system: 32

File System Layout (in sectors)
Total Range: 0 - 2003935
* Reserved: 0 - 5
** Boot Sector: 0
* FAT 0: 6 - 250
* FAT 1: 251 - 495
* Data Area: 496 - 2003935
** Root Directory: 496 - 527
** Cluster Area: 528 - 2003919
** Non-clustered: 2003920 - 2003935
```

fsstat (continue)

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```
METADATA INFORMATION
--------------------------------------------
Range: 2 - 32055046
Root Directory: 2

CONTENT INFORMATION
--------------------------------------------
Sector Size: 512
Cluster Size: 16384
Total Cluster Range: 2 - 62607

FAT CONTENTS (in sectors)
--------------------------------------------
528-559 (32) -> EOF
560-591 (32) -> EOF
592-623 (32) -> EOF
624-687 (64) -> EOF
688-719 (32) -> EOF
720-751 (32) -> EOF
```

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fls - list file and directory names in a disk image

```
d/d 4:   Project_2010
d/d 6:   Report2010
d/d 8:   Other
v/v 32055043:    $MBR
v/v 32055044:    $FAT1
v/v 32055045:    $FAT2
d/d 32055046:    $OrphanFiles
```

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istat - Display details of a meta-data structure (i.e. inode)

```
Directory Entry: 6
Allocated
File Attributes: Directory
Size: 16384
Name: REPORT~1

Directory Entry Times:
Written:        Thu Oct 20 06:36:44 2011
Accessed:       Thu Oct 20 00:00:00 2011
Created:        Thu Oct 20 06:36:42 2011

Sectors:
1488 1489 1490 1491 1492 1493 1494 1495
1496 1497 1498 1499 1500 1501 1502 1503
1504 1505 1506 1507 1508 1509 1510 1511
1512 1513 1514 1515 1516 1517 1518 1519
```

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icat - Output the contents of a file based on its inode number

```
0000000: 2e20 2020 2020 2020 2020 2010 0025 9534  .           ..%.4
0000010: 543f 543f 0000 9634 543f 2000 0000 0000  T?T?...4T? .....
0000020: 2e2e 2020 2020 2020 2020 2010 0025 9534  ..          ..%.4
0000030: 543f 543f 0000 9634 543f 0000 0000 0000  T?T?...4T?......
0000040: 422e 0064 006f 0063 0078 000f 0014 0000  B..d.o.c.x......
0000050: ffff ffff ffff ffff ffff 0000 ffff ffff  ................
0000060: 0143 0075 0073 0074 006f 000f 0014 6d00  .C.u.s.t.o....m.
0000070: 6500 7200 4400 6f00 6300 0000 5f00 3100  e.r.D.o.c..._.1.
0000080: 4355 5354 4f4d 7e31 444f 4320 0033 9534  CUSTOM~1DOC .3.4
0000090: 543f 543f 0000 2231 543f 2100 5731 0000  T?T?.."1T?!.W1..
00000a0: 4230 002e 0064 006f 0063 000f 00f4 7800  B0...d.o.c....x.
00000b0: 0000 ffff ffff ffff ffff 0000 ffff ffff  ................
00000c0: 0143 0075 0073 0074 006f 000f 00f4 6d00  .C.u.s.t.o....m.
00000d0: 6500 7200 4400 6f00 6300 0000 5f00 3100  e.r.D.o.c..._.1.
00000e0: 4355 5354 4f4d 7e32 444f 4320 0038 9534  CUSTOM~2DOC .8.4
00000f0: 543f 543f 0000 8533 543f 2200 2433 0000  T?T?...3T?".$3..
0000100: 4231 002e 0064 006f 0063 000f 00d4 7800  B1...d.o.c....x.
0000110: 0000 ffff ffff ffff ffff 0000 ffff ffff  ................
0000120: 0143 0075 0073 0074 006f 000f 00d4 6d00  .C.u.s.t.o....m.
0000130: 6500 7200 4400 6f00 6300 0000 5f00 3100  e.r.D.o.c..._.1.
0000140: 4355 5354 4f4d 7e33 444f 4320 0047 9534  CUSTOM~3DOC .G.4
0000150: 543f 543f 0000 8133 543f 2300 4346 0000  T?T?...3T?#.CF..
```

FAT Allocation Table

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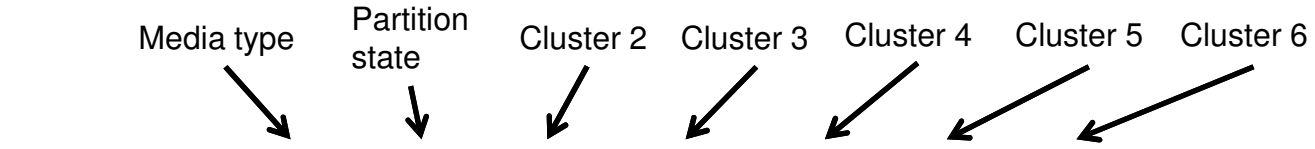


```
0000000: f8ff ffff ffff ffff ffff 0600 ffff ffff  ................
0000010: ffff ffff ffff ffff ffff ffff ffff ffff  ................
0000020: ffff ffff ffff ffff ffff ffff ffff ffff  ................
0000030: 1900 ffff ffff ffff ffff ffff ffff ffff  ................
0000040: ffff ffff ffff 2400 ffff ffff ffff ffff  ......$.........
0000050: ffff ffff ffff ffff ffff ffff ffff ffff  ................
0000060: ffff ffff ffff ffff ffff ffff 3700 ffff  ............7...
0000070: ffff ffff ffff ffff ffff ffff ffff 4000  ..............@.
0000080: 4100 ffff 4300 4400 4500 4600 4700 4800  A...C.D.E.F.G.H.
0000090: 4900 ffff 4b00 4c00 4d00 ffff 4f00 ffff  I...K.L.M...O...
00000a0: 5100 5200 5300 ffff 0000 0000 0000 0000  Q.R.S...........
00000b0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
00000c0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
00000d0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
00000e0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
00000f0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
0000100: 0000 0000 0000 0000 0000 0000 0000 0000  ................
```

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ANY QUESTIONS …