IPZe Lab

Structure of hard drive

L305

Session 3

2016

Instructor: Šimek Václav
Content of the assignment

- Physical structure of hard drive
  - Geometry, interface, fundamental terms

- Logical structure of hard drive
  - Important elements of logical-level organization
    - Master Boot Record – main bootloader
    - Partition Table – table depicting the layout of the disk
    - Boot Record – local bootloader
    - FAT, NTFS – registry of the available/occupied areas on disk
    - Root Directory – evidence of file names, attributes, etc.
  - Data area of disk

- Application WinHex – user interface, features, hints for using

- Individual solution of simple tasks
Physical structure of hard drive

- **Platters** – surface with magnetic coating for information storage, stackup of platters
- **Tracks** – concentric arrangement on HDD platter, each has a unique number, track 0 has the largest diameter
- **Cylinders** – set of all tracks with the same number on various platters
- **Heads** – reading head, distance of 3nm from the surface of a given platter
- **Sectors** – a part of circular track for data storage – mostly consists of 512B, each sector has a unique number
- **Clusters** – group of several sectors, the smallest data allocation block, it is created during the logic volume definition
Physical structure of hard drive

Communication interface of hard drive

- IDE, EIDE
- ATA
- SATA
- SCSI
- USB

- DB25m (Mac-SCSI) Aprox: 39mm
- C50m (SCSI-1) Aprox: 65mm
- IDC50m (SCSI-1) Aprox: 70mm
- IDC50f (SCSI-1) Aprox: 67mm
- HD50m (SCSI-2) Aprox: 35mm
- HD68m (SCSI-3) Aprox: 47mm
- HD68f (SCSI-3) Aprox: 45mm
- VHDC68m (SCSI-4) Aprox: 32mm
Logical structure of hard drive - description of logical data placement on a hard disk.

- Creation of logical volume - vytvoří se Master Boot Record a Partition Table
  - Fdisk utility
  - Disk management tool
  - Partition Magic
  - Linux

- System areas and data area of each volume are setup during its formatting
  - Boot Record – local bootloader
  - FAT – disk occupancy table
  - Root Directory – registry of filenames, etc.
  - Data area – actual content of files
Logical structure of hard drive

**Boot Record** – at the beginning of each logical volume.

- created during disk formatting procedure
- placed into sector number 0 of a given logical volume.
- occupies 1 sector of 512B
- it may contain local bootloader of the operating system or other executable code
**FAT** - File Allocation Table – information about the space utilization of logical volume

- information about exact location of a file and its individual parts – **cluster numbers**
- two identical copies exist
- situated immediately after the Boot Record structure
- **allocation unit (cluster)**, the most fundamental logical data unit of the disk used for data storage and organization
  - smaller cluster -> advantage for small files, potential problem for large files
  - larger cluster -> advantage for large files, potential problem for small files

Files are mapped into clusters, not into individual sectors.
Different types of FAT:

<table>
<thead>
<tr>
<th>Souborový systém</th>
<th>max. soubor</th>
<th>max. počet</th>
<th>max. oddíl</th>
<th>rok</th>
<th>použití</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAT 12</td>
<td>32 MB</td>
<td>$2^{12} = 4,077$</td>
<td>32 MB</td>
<td>1977</td>
<td>MS DOS - FDD</td>
</tr>
<tr>
<td>FAT 16</td>
<td>2 GB</td>
<td>$2^{16} = 65,517$</td>
<td>2 GB</td>
<td>1988</td>
<td>MS DOS - HDD</td>
</tr>
<tr>
<td>FAT 32</td>
<td>4 GB</td>
<td>$2^{26} = 68,235,237$</td>
<td>2 TB</td>
<td>1996</td>
<td>WIN 95 OSR2</td>
</tr>
<tr>
<td>NTFS</td>
<td>16 TB</td>
<td>$2^{32} = 4,294,967,296$</td>
<td>256 TB</td>
<td>1993</td>
<td>WIN NT, XP</td>
</tr>
<tr>
<td>ext2</td>
<td>16 GB</td>
<td>?</td>
<td>2 TB</td>
<td>1993</td>
<td>LINUX</td>
</tr>
</tbody>
</table>

Cluster – collection of sectors, the smallest allocation block where data can be placed, defined during logical volume creation.

Cluster size with respect to different FAT type:

<table>
<thead>
<tr>
<th>Volume Size</th>
<th>FAT16 Cluster Size</th>
<th>FAT32 Cluster Size</th>
<th>NTFS Cluster Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>7MB - 16MB</td>
<td>2KB</td>
<td>Not supported</td>
<td>512 bytes</td>
</tr>
<tr>
<td>17MB - 32MB</td>
<td>512 bytes</td>
<td>Not supported</td>
<td>512 bytes</td>
</tr>
<tr>
<td>33MB - 64MB</td>
<td>1KB</td>
<td>512 bytes</td>
<td>512 bytes</td>
</tr>
<tr>
<td>65MB - 128MB</td>
<td>2KB</td>
<td>1KB</td>
<td>512 bytes</td>
</tr>
<tr>
<td>129MB - 256MB</td>
<td>4KB</td>
<td>2KB</td>
<td>512 bytes</td>
</tr>
<tr>
<td>257MB - 512MB</td>
<td>8KB</td>
<td>4KB</td>
<td>512 bytes</td>
</tr>
<tr>
<td>513MB - 1GB</td>
<td>16KB</td>
<td>4KB</td>
<td>1KB</td>
</tr>
<tr>
<td>1GB - 2GB</td>
<td>32KB</td>
<td>4KB</td>
<td>2KB</td>
</tr>
<tr>
<td>2GB - 4GB</td>
<td>64KB</td>
<td>4KB</td>
<td>4KB</td>
</tr>
<tr>
<td>4GB - 8GB</td>
<td>Not supported</td>
<td>4KB</td>
<td>4KB</td>
</tr>
<tr>
<td>8GB - 16GB</td>
<td>Not supported</td>
<td>8KB</td>
<td>4KB</td>
</tr>
<tr>
<td>16GB - 32GB</td>
<td>Not supported</td>
<td>16KB</td>
<td>4KB</td>
</tr>
<tr>
<td>32GB - 2TB</td>
<td>Not supported</td>
<td>Not supported</td>
<td>4KB</td>
</tr>
</tbody>
</table>
Logical structure of hard drive

**Root Directory** - master directory – keeps information about individual files and directories
- created during logical volume formatting
- tree-like structure
- situated immediately after the 2nd copy of FAT
- it contains names of files, their extensions, information about the file size in bytes, files attributes…
- reference to the origin of a particular file (as a specific cluster number).

![Logical structure of hard drive diagram](image-url)
Logical structure of hard drive

**Data Area** – it stores actual content of files

- divided into clusters = group of several sectors
- each cluster has a unique number (address)
- takes up the largest portion of logical volume

- **allocation unit (cluster)**, the most fundamental logical data unit of the disk used for data storage and organization
  - smaller cluster -> advantage for small files, potential problem for large files
  - larger cluster -> advantage for large files, potential problem for small files

**Summary of disk logical structure:**

![Diagram of disk logical structure]
Specification of assignment tasks

Use „Disk management“ tool under Windows and create 3 logical volumes on the external hard drive in the following way:

- 1 volume – size of 100 MB, FAT16, logical volume named as X
- 2 volume – size of 100 MB, FAT32, logical volume named as Y
- 3 volume – size of 100 MB, NTFS, logical volume named as Z

Using application WinHex, study the structure of important system areas of hard drive - Master Boot (MB), Partition Table (PT), Boot Record (BR), Root Directory (RD) a FAT16, FAT32, NTFS.

Try to find out, what is going to happen with actual data and system areas upon: deleting of the file, disk formatting.

Try to explain the mechanisms which take place during the effort to restore the previously deleted file, verify the procedure by means of using WinHex application on a logical volume with file system FAT16.

Place 3 files onto the external disk drive used for this lab assignment:

file A1.txt – contains „123“
file A2.txt – contains „456“
file A3.txt – contains „789“.

Join these files together using modification of relevant disk system areas into resulting file A1, which contains all the data from previously independent files.

Study the structure of NTFS file system using the application „DiskView“. Try to take into account differences with FAT-based file systems.

Delete all the logical volumes created on the external disk used for the assignment of this lab.
**Logical volumes creation**

- **Správa disků** ve Windows - vytvořit 3 logické oddíly takto:
  1. oddíl - velikost 100 MB, FAT16, logická jednotka X
  2. oddíl - velikost 100 MB, FAT32, logická jednotka Y
  3. oddíl - velikost 100 MB, NTFS, logická jednotka Z
Logical volumes creation

<table>
<thead>
<tr>
<th>Disk 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Základní</td>
</tr>
<tr>
<td>74,53 GB</td>
</tr>
<tr>
<td>Online</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FAT16 (X:)</th>
</tr>
</thead>
<tbody>
<tr>
<td>102 MB FAT</td>
</tr>
<tr>
<td>V pořádku</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FAT32 (Y:)</th>
</tr>
</thead>
<tbody>
<tr>
<td>102 MB FAT32</td>
</tr>
<tr>
<td>V pořádku</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NTFS (Z:)</th>
</tr>
</thead>
<tbody>
<tr>
<td>102 MB NTFS</td>
</tr>
<tr>
<td>V pořádku</td>
</tr>
<tr>
<td>74,23 GB</td>
</tr>
<tr>
<td>Nepřiřazeno</td>
</tr>
</tbody>
</table>

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**Zkopírovat z D:**

Vytvořit

![Windows Explorer screenshot](image)
Disk edit - WinHex

IPZe

Structure of hard drive
Disk edit - WinHex

<table>
<thead>
<tr>
<th>Name</th>
<th>Ext</th>
<th>Created</th>
<th>Modified</th>
<th>Accessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>test.exe</td>
<td>exe</td>
<td>89 600 06.10.2008 09:05:01</td>
<td>14.05.2002 20:05:18</td>
<td>06.10.2008</td>
</tr>
<tr>
<td>(Root directory)</td>
<td></td>
<td>16 384</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Volume Information</td>
<td></td>
<td>2 048 06.10.2008 09:05:01</td>
<td>06.10.2008 09:05:02</td>
<td>06.10.2008</td>
</tr>
<tr>
<td>a1.txt</td>
<td>txt</td>
<td>3 06.10.2008 09:04:17</td>
<td>06.10.2008 09:04:28</td>
<td>06.10.2008</td>
</tr>
<tr>
<td>a2.txt</td>
<td>txt</td>
<td>3 06.10.2008 09:04:37</td>
<td>06.10.2008 09:04:42</td>
<td>06.10.2008</td>
</tr>
<tr>
<td>a3.txt</td>
<td>txt</td>
<td>3 06.10.2008 09:04:50</td>
<td>06.10.2008 09:04:56</td>
<td>06.10.2008</td>
</tr>
</tbody>
</table>

Offset

<table>
<thead>
<tr>
<th>Offset</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000000000</td>
<td>EB</td>
<td>3C</td>
<td>90</td>
<td>4D</td>
<td>53</td>
<td>44</td>
<td>4F</td>
<td>30</td>
<td>00</td>
<td>02</td>
<td>04</td>
<td>08</td>
<td>00</td>
</tr>
<tr>
<td>000000016</td>
<td>02</td>
<td>00</td>
<td>02</td>
<td>00</td>
<td>00</td>
<td>F8</td>
<td>CC</td>
<td>FF</td>
<td>00</td>
<td>3F</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>000000032</td>
<td>8E</td>
<td>2F</td>
<td>03</td>
<td>00</td>
<td>80</td>
<td>00</td>
<td>29</td>
<td>34</td>
<td>4E</td>
<td>4F</td>
<td>20</td>
<td>4E</td>
<td>41</td>
</tr>
<tr>
<td>000000048</td>
<td>4D</td>
<td>45</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>46</td>
<td>36</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>33</td>
<td>C9</td>
</tr>
<tr>
<td>000000064</td>
<td>8E</td>
<td>D1</td>
<td>BC</td>
<td>FO</td>
<td>7B</td>
<td>8E</td>
<td>D9</td>
<td>8E</td>
<td>CO</td>
<td>FC</td>
<td>BD</td>
<td>00</td>
<td>7C</td>
</tr>
<tr>
<td>000000080</td>
<td>38</td>
<td>4E</td>
<td>24</td>
<td>7D</td>
<td>24</td>
<td>8B</td>
<td>C1</td>
<td>01</td>
<td>72</td>
<td>1C</td>
<td>83</td>
<td>EB</td>
<td>3A</td>
</tr>
<tr>
<td>000000096</td>
<td>66</td>
<td>A1</td>
<td>1C</td>
<td>7C</td>
<td>26</td>
<td>66</td>
<td>3B</td>
<td>57</td>
<td>FC</td>
<td>75</td>
<td>06</td>
<td>80</td>
<td>CA</td>
</tr>
<tr>
<td>000000112</td>
<td>02</td>
<td>88</td>
<td>56</td>
<td>02</td>
<td>80</td>
<td>C3</td>
<td>10</td>
<td>C9</td>
<td>8A</td>
<td>46</td>
<td>10</td>
<td>98</td>
<td>F7</td>
</tr>
<tr>
<td>000000128</td>
<td>66</td>
<td>16</td>
<td>03</td>
<td>46</td>
<td>1C</td>
<td>13</td>
<td>56</td>
<td>0E</td>
<td>13</td>
<td>D1</td>
<td>8B</td>
<td>76</td>
<td>11</td>
</tr>
</tbody>
</table>

Boot sector

- Boot sector (template)
- FAT 1
- FAT 2

Root directory
- Root directory (template)

Search directory (up)
- Search directory (down)
- Volume slack
Disk edit - WinHex

- Don’t forget to use **Volume Snapshot** operation after any change on disk.
NTFS file system edit - DiskView

DiskView

Disk:

- Free clusters on disk: 25599577
- Location of file:
- Content of cluster:
- DiskInfo:
- MFT records:
- About:

Volume size: 99998 MB
Total sectors: 204796619
Total clusters: 25599577
Free clusters: 19288803
Free space: 75344 MB (75%)
Bytes per sector: 512
Bytes per cluster: 4096
Bytes per MFT record: 1024
Clusters per MFT record: 0
MFT size: 320 MB (0% of drive)
MFT start cluster: 786432
MFT zone clusters: 868448 - 3986400
MFT zone size: 12176 MB (12% of drive)
MFT mirror start: 12799788
Cluster size is 4096

$MFT
$MFTMirr
$logfile
$volume
$attrdef
$bitmap
$boot
$badclus
$quota
$upcase
Thank you for the attention…