# The File System

## The User Perspective

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# The purpose of today's lecture

- General Overview of The File System Module
- File Concept
- Directory Concept

# Bibliography


- Andrew Tanenbaum, *Modern Operating Systems*, 2nd Edition, 2001, Chapter 6, pg. 380 – 398.


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# Outline



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# Context

- users need to **store** and **retrieve**
  - **persistent data**
  - **large amount of data**
- users need to **share data**
- ⇒ OS should
  - **provide services** for such needs
  - **manage** storage devices (area) and stored data

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  - ⇒ part of OS
- the **interface** between the user and the physical storage devices
  - *provides* the users access to the storage area
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  - hides the complexity of physical storage devices
  - abstract concepts: file and directory
  - ⇒ its name: *File System*
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  - interacts directly with storage devices
  - ⇒ contains a hardware dependent layer (code modules)

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# File System Architecture. General View

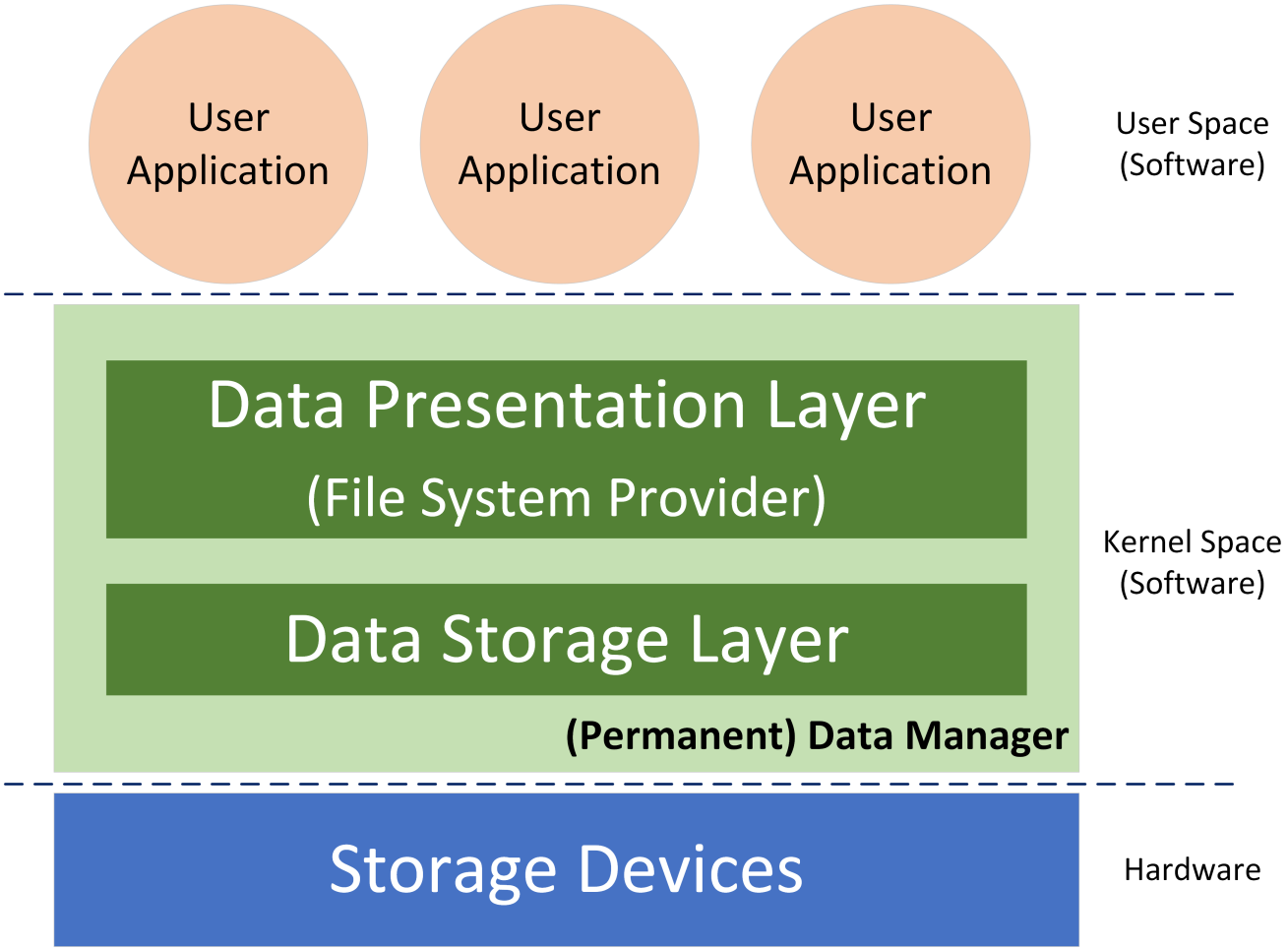


Figure: Data Manager's Layers. What we call "File System" is the way the "Data Manager" makes visible the data storage space to users.

# File System Architecture. Detailed View

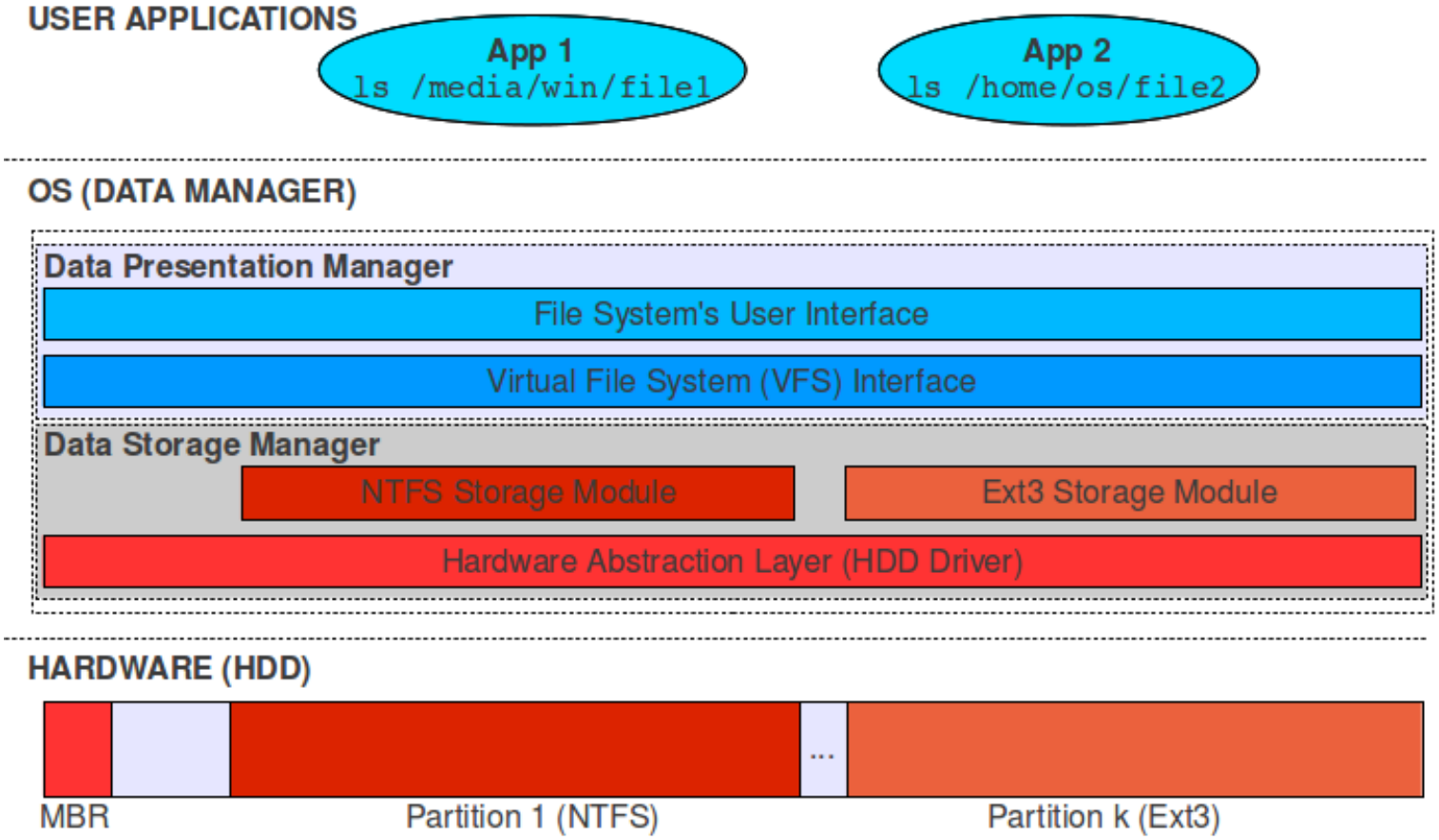


Figure: Data Manager's Components

# Outline

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# Definition. User Perspective

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  - anything the user wants to store must be placed in a file
- provides a (convenient) way to
  - **store** the information on storage devices
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- **a container**, i.e. **a box**
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**The file is the basic abstract concept for storing user data!**

# Definition. OS (Internal) Perspective

- an abstraction mechanism: a *container*
  - models the way data is provided to users
  - does not necessarily correspond to the way data is stored (on physical devices)
- OS must
  - **store** the container's contents on storage area
  - **retrieve** back later the container's contents
- the file maps the user view of data to the physical data
  - identifies on physical devices and links together physical data (i.e. chunks of bytes) belonging to a file

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# File's Components


- **data**: user's useful information placed in the container
- **metadata**: description associated to stored data
  - needed, maintained and sometimes imposed by OS
  - some fields also used by user
- the two components **can be stored in different parts** on a storage area
  - there is a link maintained from metadata to data
  - ⇒ FS always **starts from a file's metadata** in order to access the file

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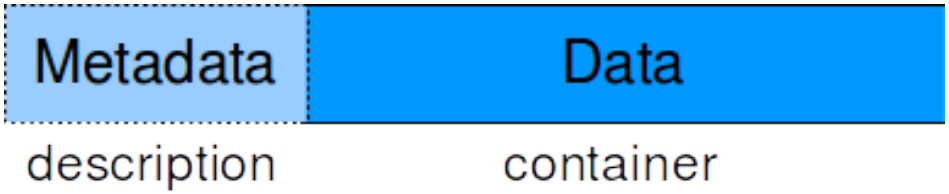


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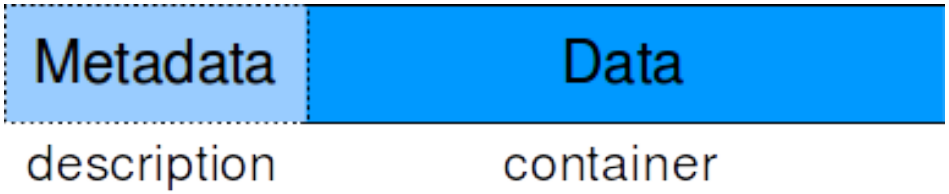


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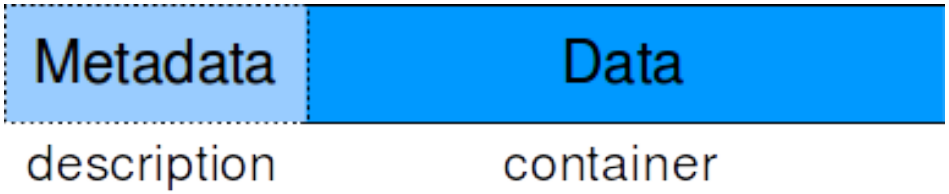


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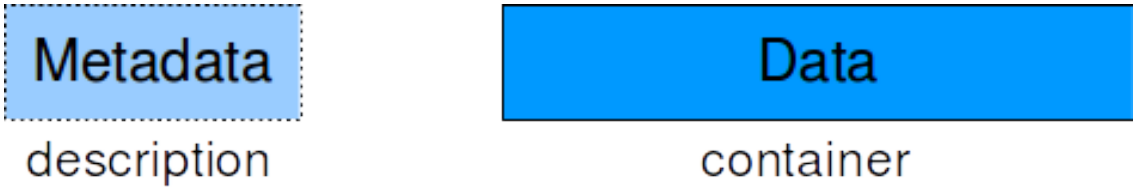


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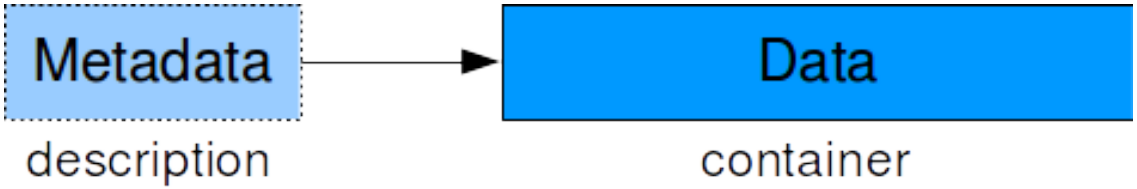


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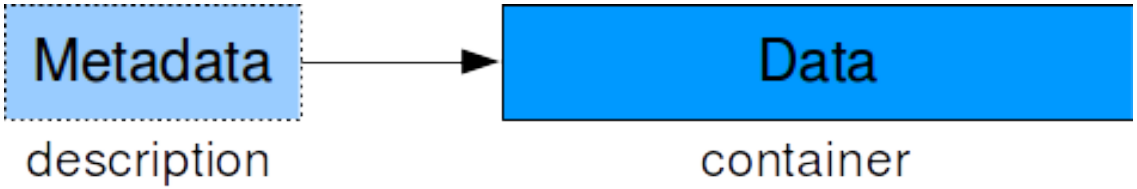


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# File Metadata: Name

- the user's way to **identify** (refer to) a file
- **must be unique** (there are though some exceptions!)
- each file must have (at least) a name
- consists of a **string of characters**
  - upper vs. lower letters, char sets
  - its length is generally limited
- file name's **extension**
  - normally **not imposed by OS**
  - *rarely*: may be recognized and used by the OS
  - *usually*: **a user-space convention** to provide hints about file's contents
  - required by some application (e.g. *gcc* requires .c)
  - examples: `book.docx`, `letter.odt`, `setup.exe`, `arch.tar.gz`, `progr.c`, `image.jpg`

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  - examples: `book.docx`, `letter.odt`, `setup.exe`, `arch.tar.gz`, `progr.c`, `image.jpg`

# File Metadata: Name

- the user's way to **identify** (refer to) a file
- **must be unique** (there are though some exceptions!)
- each file must have (at least) a name
- consists of a **string of characters**
  - upper vs. lower letters, char sets
  - its length is generally limited
- file name's **extension**
  - normally **not imposed by OS**
  - *rarely*: may be recognized and used by the OS
  - *usually*: **a user-space convention** to provide hints about file's contents
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**From the OS perspective every filename is just a string of (unrestricted) characters!**

# File Metadata: Type

- Regular files
  - Contain user data (text or binary)
- Directories
  - System files used to organize file space
- Links
  - System files used to redirect the access to other files
- Special files
  - Model I/O devices
  - *Character*: terminals, mouse, etc.
  - *Block*: disks
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# File Metadata: Structure

- **file's structure = the way the file's contents is organized and interpreted**
- possible strategies
  1. **no structure**: just a *sequence of bytes*
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     - tree of records (e.g. B-trees)

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    - -: additional OS code
    - -: restrictions, rigidity
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  - **if, no**
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# File Metadata: Type vs. Structure – Real Life OSes

- **no structure for regular files**
  - *text* vs. *binary* files: just a user convention
  - basically, **all files are binary**, i.e. each file's contents must be handled specifically by applications using it
  - ⇒ *text file* is just a particular file type
- ⇒ **flexibility** (*separate mechanism by policy*)
- **yet**, every OS recognizes its own executable files

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**From the OS perspective every file is just a sequence of bytes!**

# Question

**Yet, from the user perspective . . .** how would you classify the following files in terms of **text** vs **binary**, based on their filename extension?

1. `program.c`
2. `archive.zip`
3. `paper.pdf`
4. `index.html`
5. `persons.xml`
6. `app.java`
7. `cv.docx`

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# File Metadata: Attributes

- system attributes
  - type
  - length
  - owner
  - access permissions (rights): basically *read*, *write* and *execute*
  - time stamps (e.g. creation time, last access time, last modification)
  - addresses of allocated blocks for that file
    - named during that course *Block Addresses Table* (BAT)
    - the link between metadata and data
  - ...
- user attributes (if supported)
  - anything the user wants
  - examples: *source Web address* (for an html file), *place* (for an image file), *author* (for a document) etc.

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# File Metadata: Attributes

- system attributes
  - type
  - length
  - owner
  - access permissions (rights): basically *read*, *write* and *execute*
  - time stamps (e.g. creation time, last access time, last modification)
  - addresses of allocated blocks for that file
    - named during that course *Block Addresses Table* (BAT)
    - the link between metadata and data
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# File Access Method

- **sequential** access
  - **impose an order** on the way the bytes are accessed
  - could be imposed by the storage device (e.g. tapes)
  - could be imposed by the nature of the file's contents
    - e.g. **specific for directories**
- **random** access
  - accesses the bytes or records **out of order**
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# Outline

# Definition. User Perspective

- the way to **organize / classify files**
  - when too many, difficult to find them based just on their name
- a **collection / class** of related elements (files)
  - a file could be placed in a directory (or more?)
  - ⇒ directory's name is a sort of additional (user) metadata associated to the file
- reduces the size of the filename space
  - files in different directories could have the same name
- imposes a structure / **hierarchy** on the file space
  - helps the user locating files easier in huge file spaces
  - **finding files visually** in the hierarchy is based on **navigation**
    - ⇒ **search** based on **criteria** is a better choice
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**The directory is the abstract concept for organizing user files!**

# Definition. OS (Internal) Perspective

- an abstraction mechanism of grouping files
- a **container**: data (bytes) that must be stored
  - a **special file managed by OS** transparently from user
  - i.e. directory's bytes are interpreted by the OS and user-applications provided directory's elements
  - usually organized as specialized searching data structures, e.g. B-trees
- it also **consists of data and metadata**
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# Definition. OS (Internal) Perspective

- an abstraction mechanism of grouping files
- a **container**: data (bytes) that must be stored
  - a **special file managed by OS** transparently from user
  - i.e. directory's bytes are interpreted by the OS and user-applications provided directory's elements
  - usually organized as specialized searching data structures, e.g. B-trees
- it also **consists of data and metadata**
  - very similar to a regular file
  - $\Rightarrow$ just a FS-element from the OS perspective

# Directory Hierarchy

- types
  - single-level directory systems
  - two-level directory systems
  - **hierarchical** directory systems
    - the most general form: **tree** or **graph**
- **file paths**
  - the way of **identify a file in a hierarchy**
  - a list of consecutive nodes ending with the file name

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# File Paths

- **absolute paths**
  - starting node is the **root directory**
  - examples
    - `c:\Program Files\Application\run.exe` (Windows)
    - `/home/students/adam/program.s` (Linux)
  - usage: access files at known fixed places
- **relative paths**
  - not staring from the root directory
    - `./Application/run.exe`
    - `../students/adam/program.s`
  - each application has its own current directory associated to it
  - examples
    - `./Application/run.exe` (Windows)
    - `../students/adam/program.s` (Linux)
  - special notations (directories)
    - `.` current directory
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    - `./bin/run.exe`, `../bin/run.exe`
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    - `./bin/run.exe`, `../lib/libs.a`
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  - examples
    - `./program.exe` run as a subtree
    - `../lib/libs.a` (`../` means parent directory)
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**The directory concept imposes a hierarchy on the file space, requiring a path in order to identify a file!**

# Question

Supposing the current working directory of an application is "`/home/os`", which will be the corresponding absolute paths for the following relative paths?

1. `file_1`
2. `./file_2`
3. `project/file_3`
4. `../file_4`
5. `../../file_5`
6. `../../../../file_6`
7. `../../etc/file_7`
8. `./../../etc/apache2/././../../home/os/./file_8`

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# Operations On Directories

- create
- delete
- rename
- opendir
- readdir
  - **sequential access**
  - positioning not allowed anywhere
- rewind
- "write" (**not directly allowed**)
  - add elements (create directories and files)
  - delete elements (delete directories and files)
- close

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# Outline

# What We Talked About

- **file system (FS)** as an OS component
  - role
  - general structure
- **file** concept
  - used for **storing user data**
  - components: **data** (container component) and **meta-data** (description component)
  - meta-data fields: name, types, attributes etc.
  - **structure**: sequence of bytes, specialized collection of elements
- **directory** concept
  - used for **organizing the file space**
  - a system file: its bytes are interpreted by the OS and provided as a collection of elements
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# What We Talked About

- **file system (FS)** as an OS component
  - role
  - general structure
- **file** concept
  - used for **storing user data**
  - components: **data** (container component) and **meta-data** (description component)
  - meta-data fields: name, types, attributes etc.
  - **structure**: sequence of bytes, specialized collection of elements
- **directory** concept
  - used for **organizing the file space**
  - a system file: its bytes are interpreted by the OS and provided as a collection of elements
  - imposes a **hierarchy**
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# Lessons Learned

- the basic storage unit for the user (applications) is the file
  - ⇒ storing just a single byte of data needs placing it in a file
- OS usually not involved in the interpretation of a file's contents
  - ⇒ file structure (format) is the user-application business
- text vs binary files is just a user convention
  - from the OS perspective all files consist just in a sequence of bytes
- FS organization, i.e. classifying files, is a real need
  - helps the user to navigate visually in the FS space in order to find her files
  - does not help (too much) the user applications finding files

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