

# CS 3502

# Operating Systems

## File system

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<https://kevinsuo.github.io/>

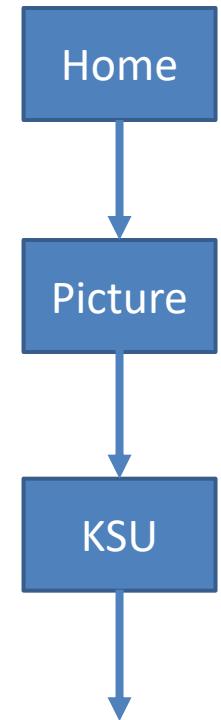
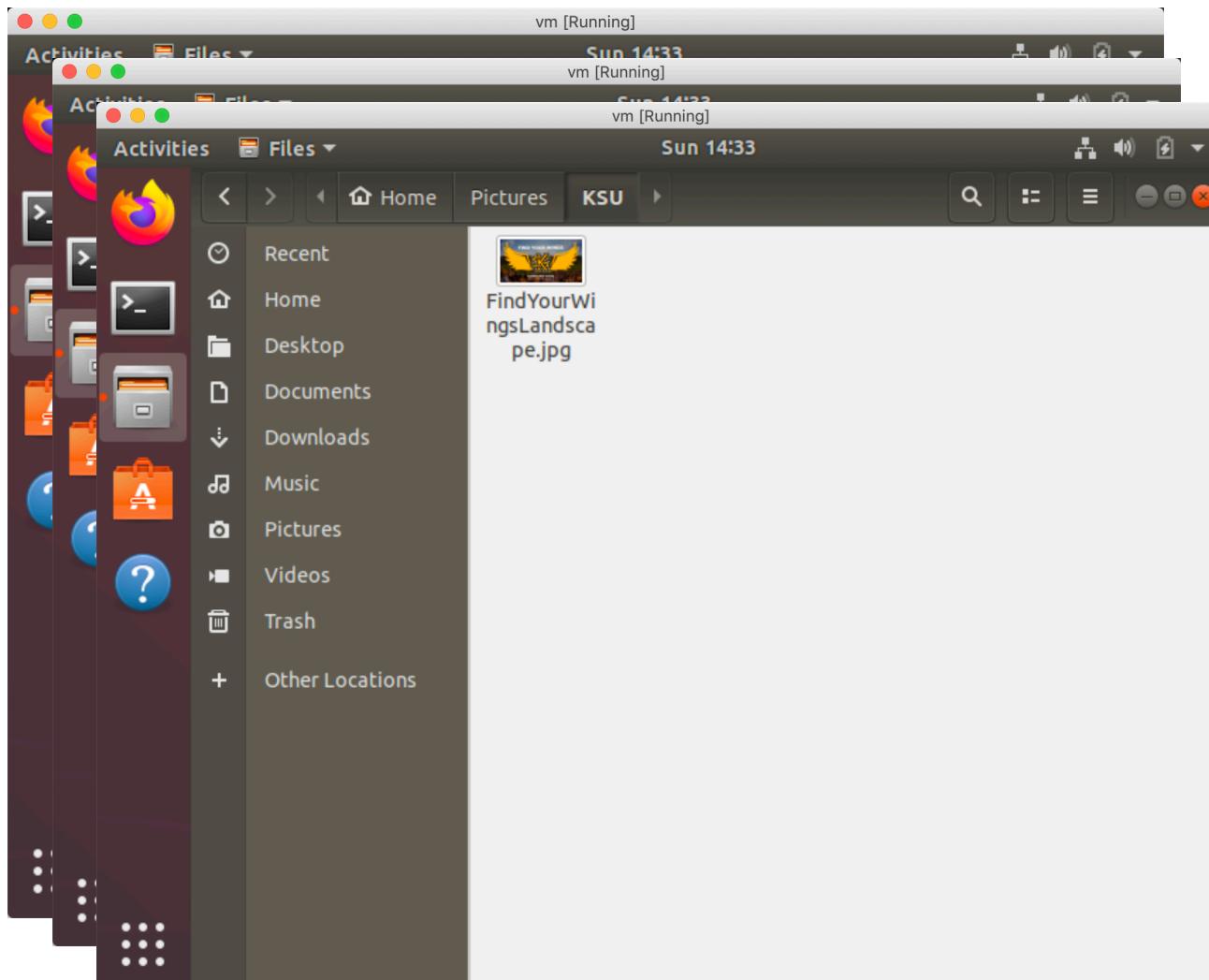
# Outline

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- What is File System?
  - The OS component that organizes data on raw storage device
- File implementation
  - Contiguous allocation, Linked list allocation, File allocation table (FAT), Index allocation
- Directory implementation
  - Fixed entry, i-node index
- Shared Files
  - Hard link vs soft link
- Virtual file system

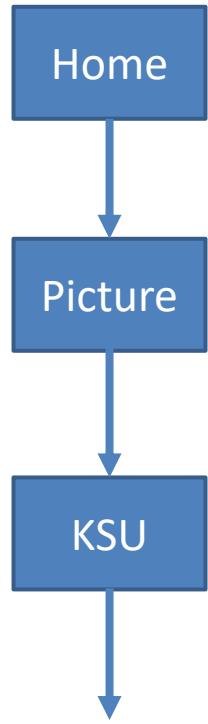


# What is a File System?

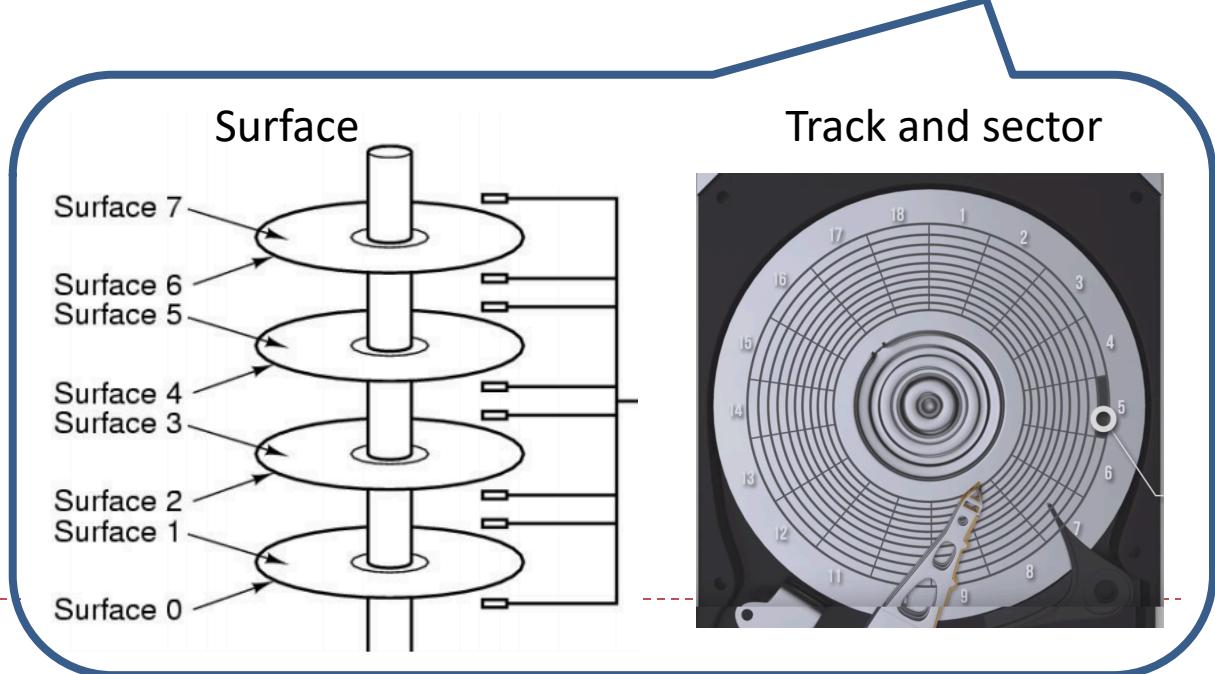
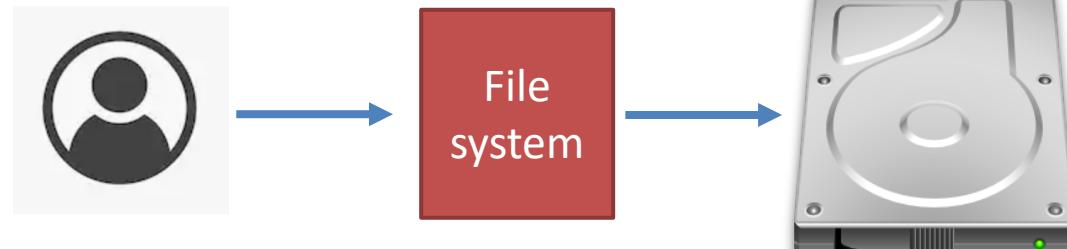


# What is a File System?

What you see...



Reality



# Library system: manages how and where book is stored, managed and accessed

The screenshot shows the homepage of the Kennesaw State University Library System. The top navigation bar includes links for MyKSU, A-Z Index, Directories, Campus Maps, Apply, Visit, Give, and a search bar. Below the navigation is a yellow banner with links for About KSU, Academics, Admissions, Athletics, Campus Life, Research, and Global. A message at the bottom of the banner indicates library hours: Sturgis Library: 1:00 P.M. - 9:00 P.M. | Johnson Library: 1:00 P.M. - 9:00 P.M.

The main content area features a sidebar with links for Home, Services, Resources, About, Useful Links, Faculty Subvention Fund, and Undergraduate Research Award. The main content area has a heading "Research Tools" with tabs for SuperSearch, Books, Journal Holdings, and Research Guides. It includes a search bar, search options (Keyword, Title, Author), and links for Advanced Search, Find a Database, and Databases by Subject & Type. Below this is a section titled "FAQs - Ask about the Library" with a search bar and a "Search" button. At the bottom, there are two promotional boxes: one for a crystal ball service and another for study rooms.

**Library System**

**Research Tools**

SuperSearch Books Journal Holdings Research Guides

Books, Articles, eBooks, Videos, and more **Search**

Keyword  Title  Author

Advanced Search Find a Database Databases by Subject & Type

**FAQs - Ask about the Library**

Ask a question about the Library **Search**

We're available. Chat now!

Look into our crystal ball! Get your scary predictions here and act.

Need a study room?

RESERVE

# What is a File System?

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- File system is the OS component that manages how and where data is stored, managed and accessed on the raw storage.
- Data in File system:
  - Raw data, by itself, is just a meaningless sequence of bits and bytes.
  - Metadata is the information that describes the data.
    - ▶ Also called attributes.
    - ▶ Without meta-data, data itself will be incomprehensible.



# Raw Data and Metadata

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- Metadata is the data about data
- Metadata is usually structured data
  - Metadata of books such as title, version, published data, related descriptions, language, review, etc.
- Metadata is extracted from information resources to describe its characteristics and content,
- Meta is used for organization, description, preservation, management, search, etc.



Keyword

world history

Search



Basic Search Advanced Search Search History

Detailed Record

PlumX Metrics

See in GIL-Find

## Related Information

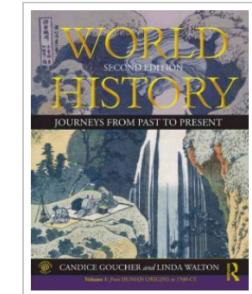
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# World history [electronic resource] Volume 1, From human origins to 1600 CE journeys from past to present / Candice Goucher and Linda Walton.

Language:	English
Authors:	<a href="#">Goucher, Candice</a>
Publication Information:	Oxfordshire, England ; New York : Routledge, c2013.
Edition:	2nd ed.
Publication Date:	2013
Physical Description:	1 online resource (2 v. (xx, 736 p.) ill. (chiefly col.), col. maps
Publication Type:	Book; eBook
ISBN:	0-415-67002-0 1-135-08821-7 0-203-06972-2 1-135-08822-5
OCLC:	857067534
Online Access:	<a href="#">Online Access</a>
Accession Number:	ken.9919771319502931
Database:	Kennesaw Alma Catalog

**Metadata**

# Raw Data and Metadata

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With the growing reliance on the ubiquitous availability of IT systems and services, these systems become more global, scaled, and complex to operate. To maintain business viability, IT service providers must put in place reliable and cost efficient operations support ...  
☆ 99 All 2 versions

```
@inproceedings{levin2019aiops,
    title={AIOps for a Cloud Object Storage Service},
    author={Levin, Anna and Garion, Shelly and Kolodner, Elliot K and Lorenz, Dean H and Barabash, Katherine and Kugler, Mike and McShane, Niall},
    booktitle={2019 IEEE International Congress on Big Data (BigDataCongress)},
    pages={165--169},
    year={2019},
    organization={IEEE}
}
```

▶ CS 3502 Kennesaw State University Operating Systems

# Raw Data and Metadata

BASIS FOR COMPARISON	DATA	METADATA
Basic	Data is a set of facts and statistics can that be operated, referred or analyzed.	Metadata describes relevant information about the data.
Information	Data can or can not be informative (e.g., raw data like 0101).	Metadata is always informative.
Structure	Data may or may not have been processed or structured.	Metadata is always a processed and structured data.



project1.docx Info

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Modified: Sep 10, 2019 at 11:24 AM

Add Tags...

General:

Kind: Microsoft Word document (.docx)  
Size: 765,942 bytes (766 KB on disk)  
Where: Macintosh HD ▷ Users ▷ ksuo ▷ Desktop  
Created: September 10, 2019 at 11:24 AM  
Modified: September 10, 2019 at 11:24 AM

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 Locked

More Info:

Last opened: September 25, 2019 at 2:06 PM

Name & Extension:

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You can read and write

Name	Privilege
ksuo (Me)	Read & Write
staff	Read only
everyone	Read only

+

-

⚙️

🔒

# What is a File System?

Data



project1.docx

Metadata

# What is a File System?

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- A File System defines
  - Format of the data objects and the format/meaning of meta-data associated with each data object. (store)
    - ▶ E.g. File name, permissions, and size of a file.
  - Location of the individual data blocks for each data object. (access)
  - A framework to manage free space on the raw storage. (manage)



# Common file system: ext3, ext4, btrfs, etc.

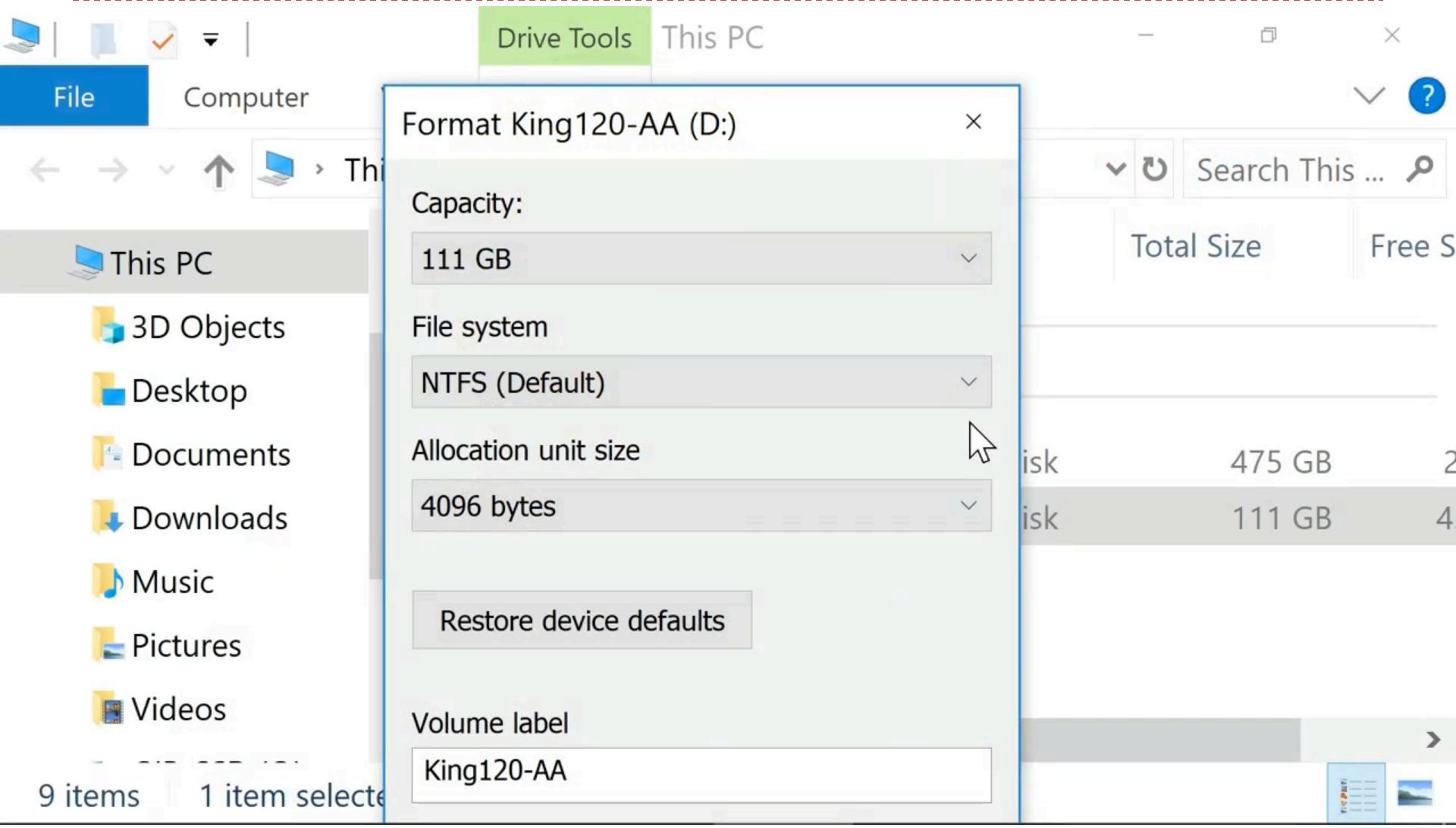
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- Linux
  - Ext: extended file system (1992)
  - Ext2: second extended file system (1993)
  - Ext3: third extended filesystem (2001)
  - Ext4: fourth extended filesystem (2008)
  - Btrfs: file system based on the copy-on-write (2009)
- Windows
  - FAT32, exFAT
  - Ntfs: New technology file system developed by Microsoft (1993)
- Apple
  - HFS: Hierarchical File System (1985)
  - Apfs: Apple file system for (2017)

*Not used*

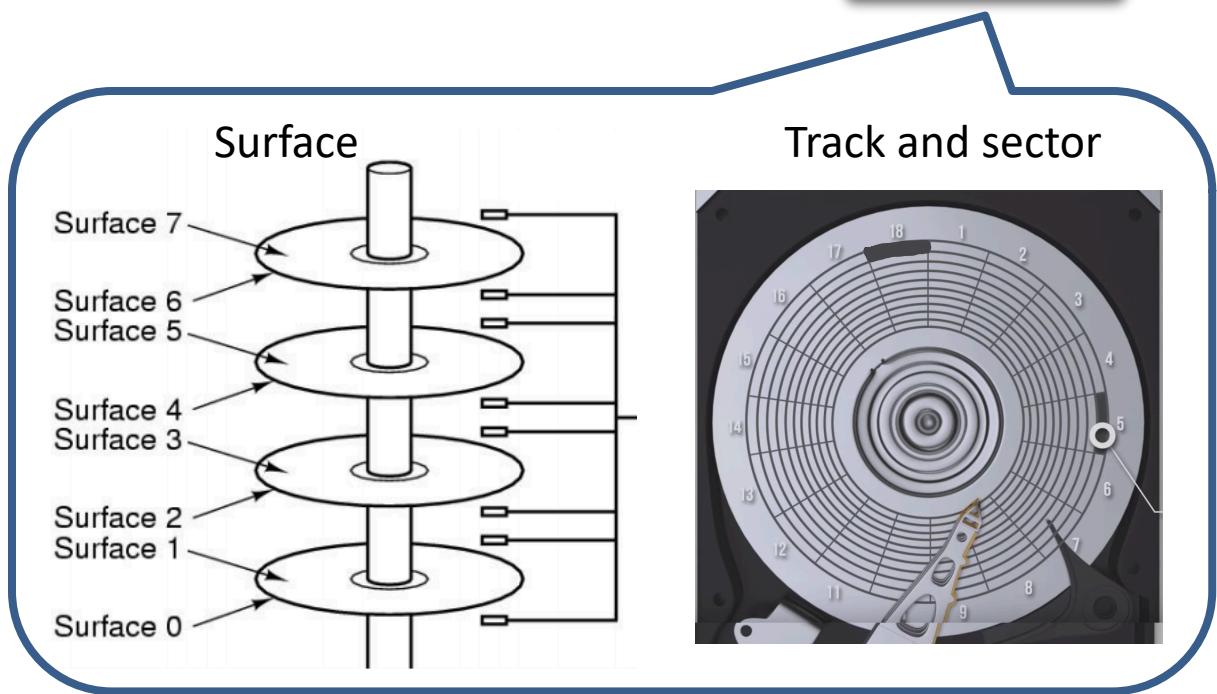


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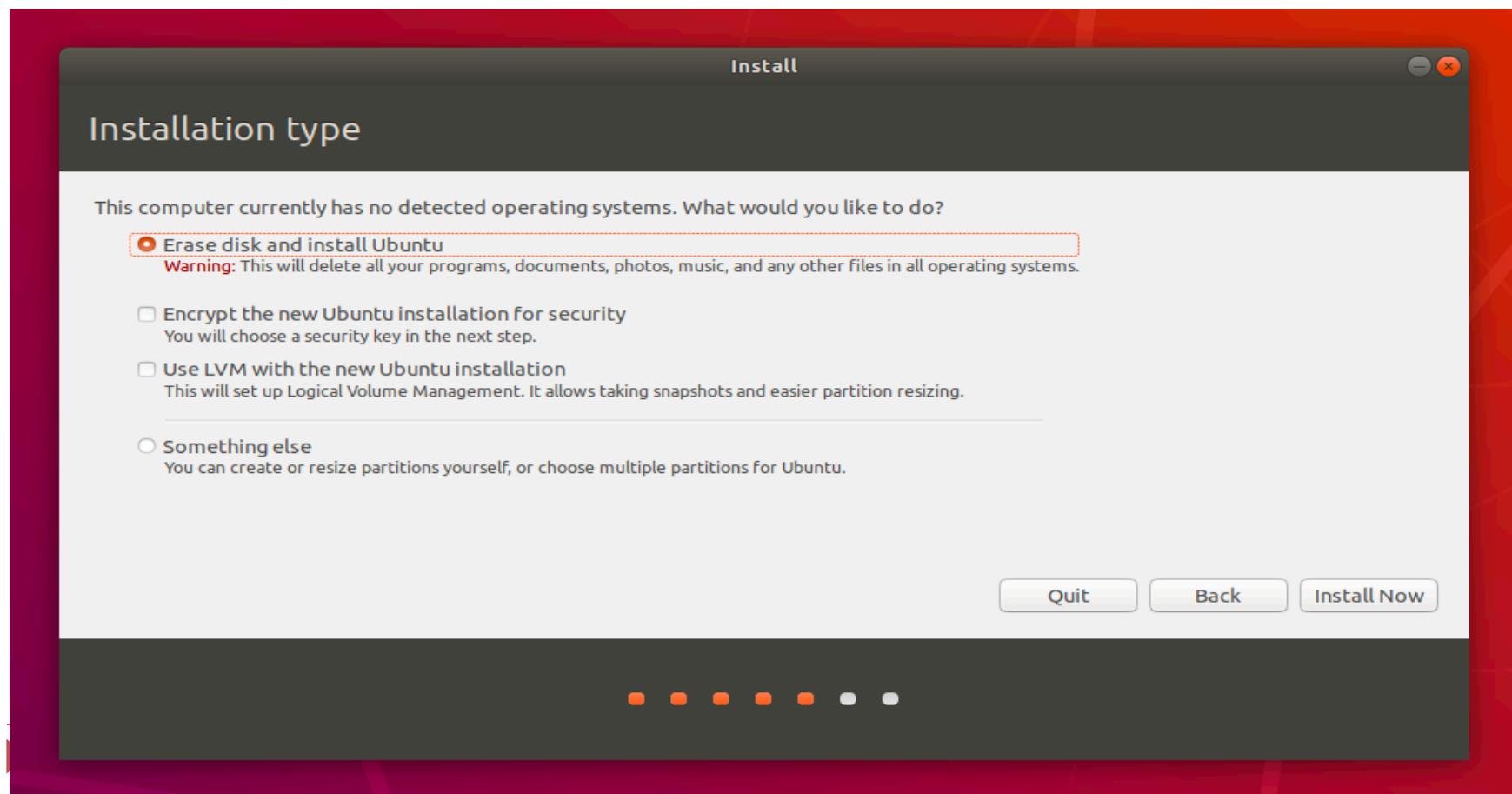
# Unit of File System: Blocks

- Files and directories are allocated in blocks
- Block size is usually a multiple of the sector size



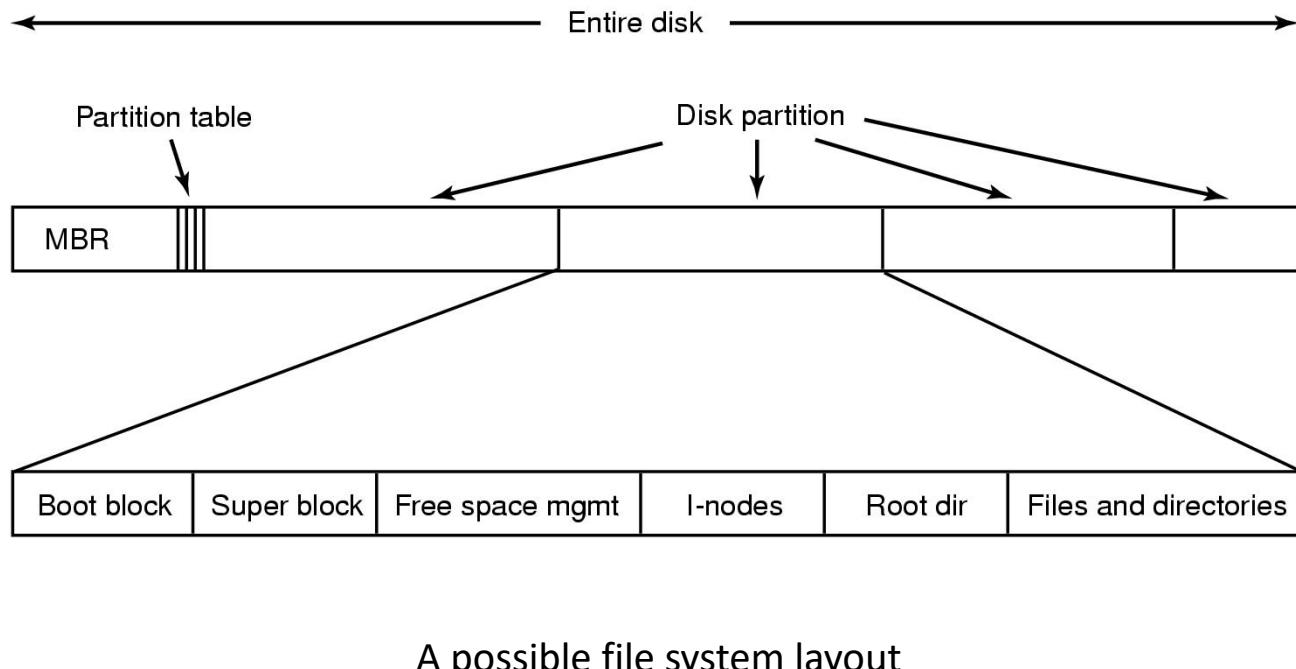
# What will happen to the disk when you have file system?

Free space



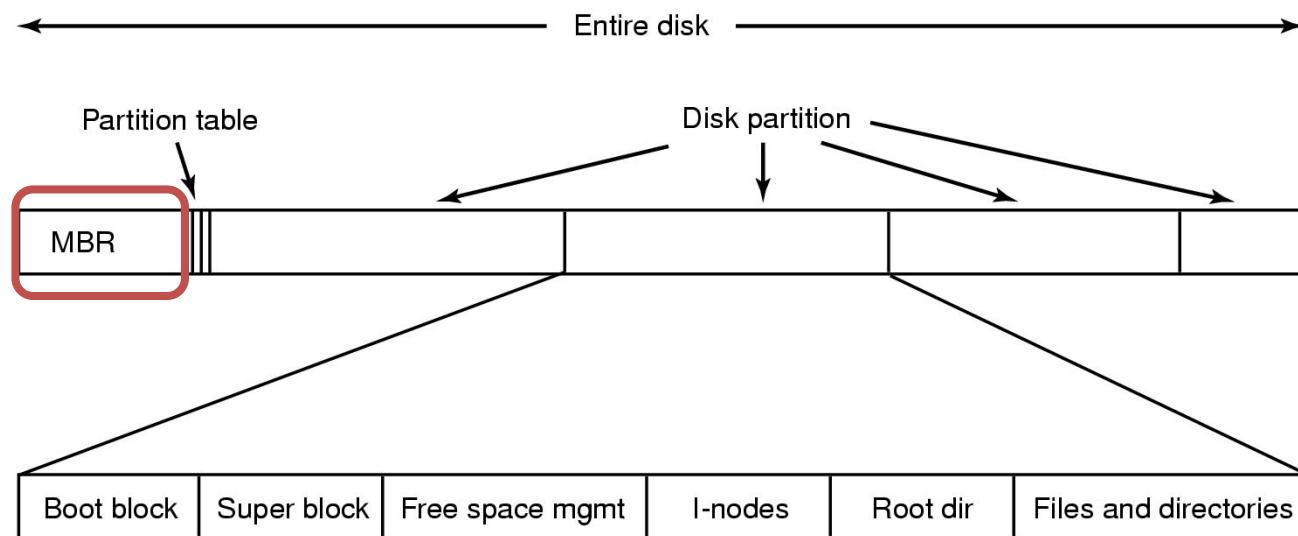
# File System layout

- Most disks can be divided into one or more partitions



# File system layout

- *Master Boot Record* is used to boot the computer

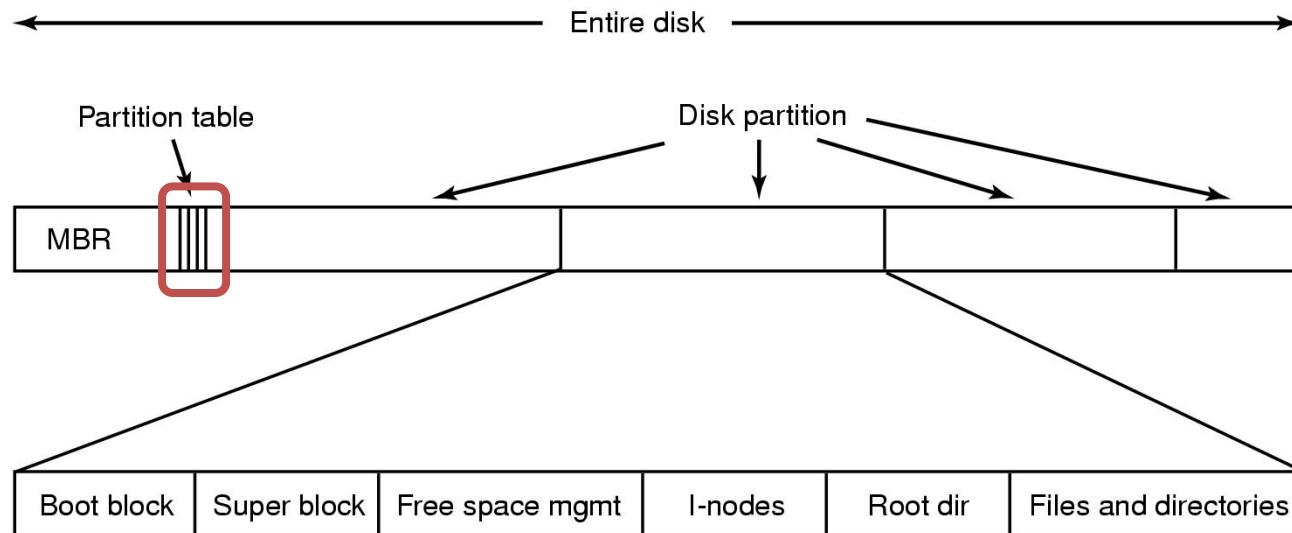


A possible file system layout



# File system layout

- *Partition table* is present at the end of MBR.
- This table gives the starting and ending addresses of each partition.

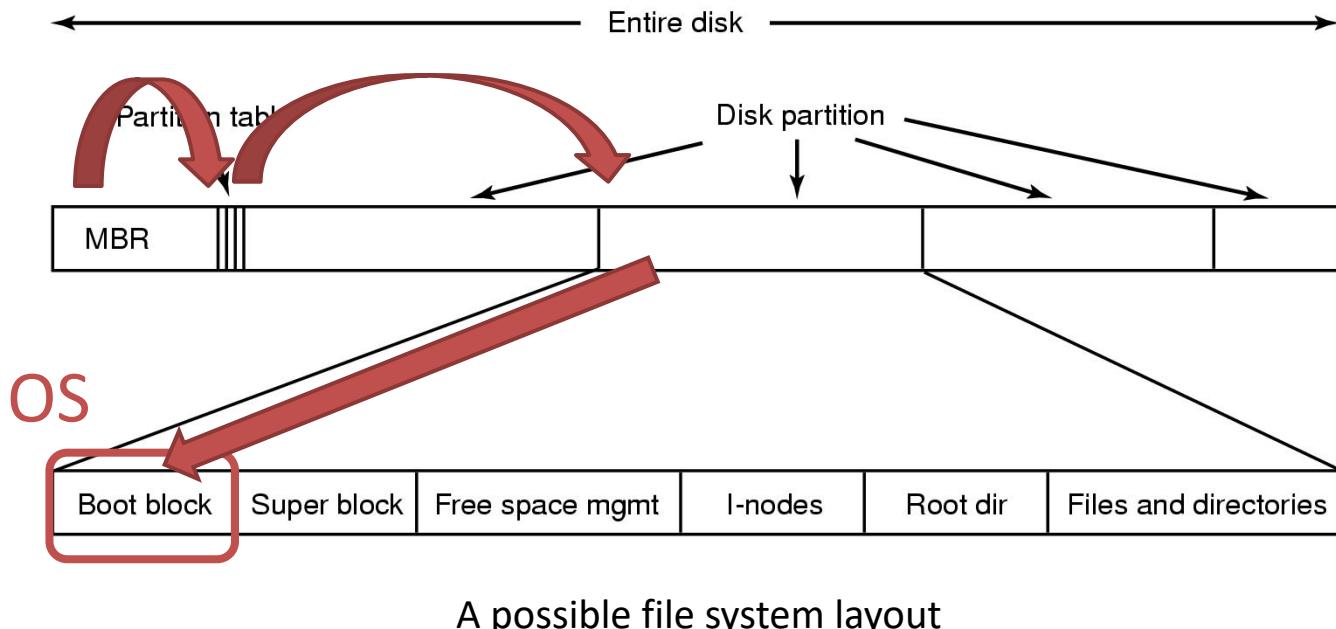


A possible file system layout



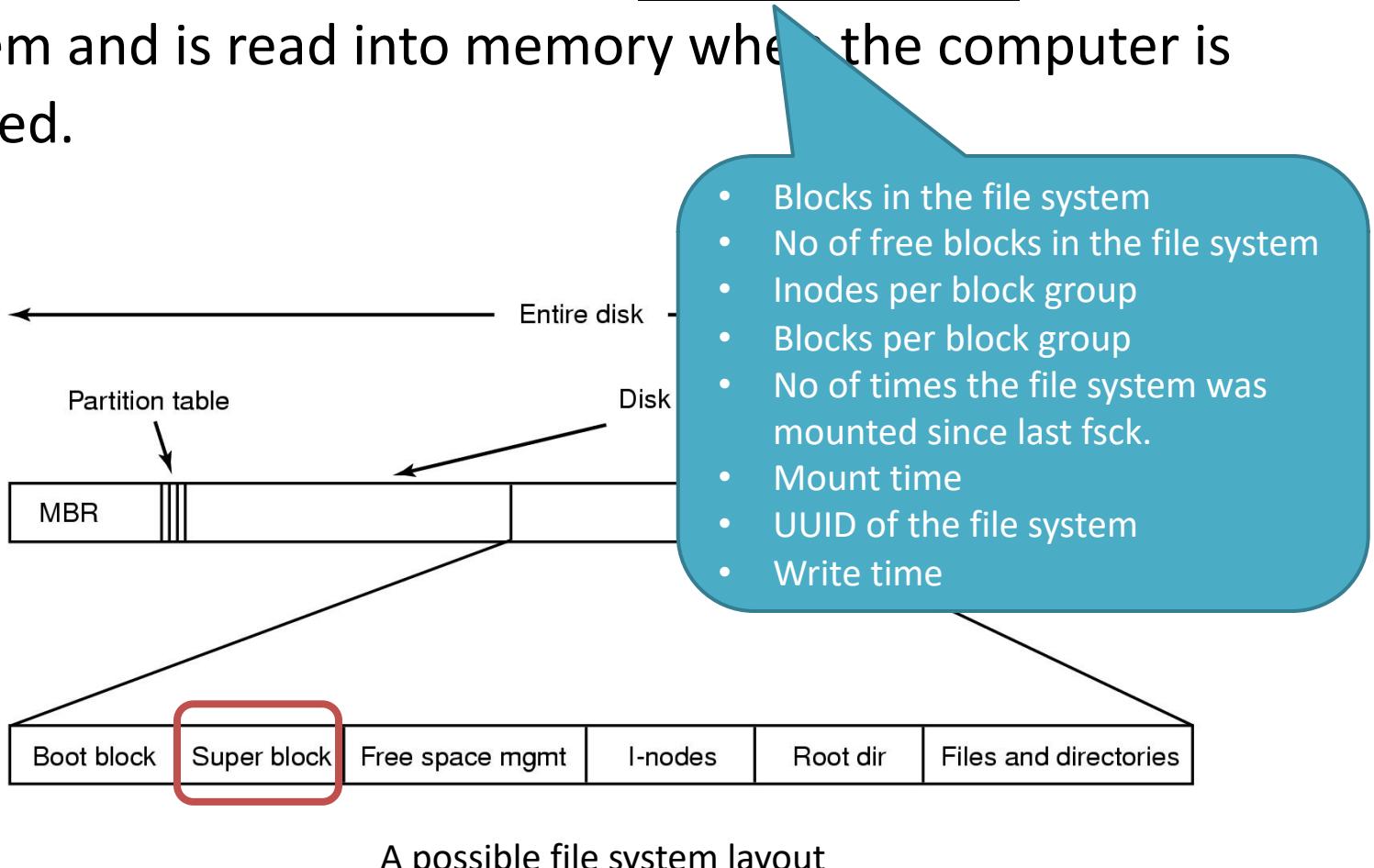
# File system layout

- **Boot Block:** When the computer is booted, the BIOS reads in and executes the MBR.
- The first thing the MBR program does is locate the active partition, read in its first block, which is called the **boot block**, and execute it.
- The program in the boot block loads the operating system contained in that partition.



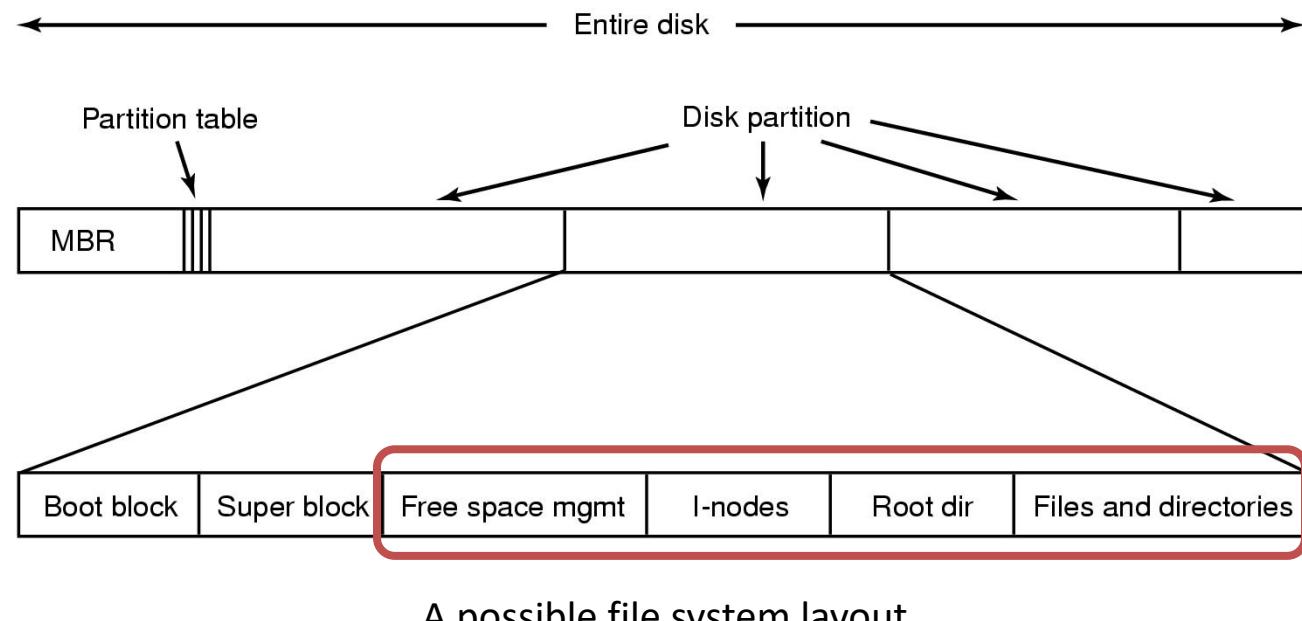
# File system layout

- ***Super Block***: It contains all the key parameters about the file system and is read into memory when the computer is booted.



# File system layout

- *Rest*: free space management, files and directories



# Outline

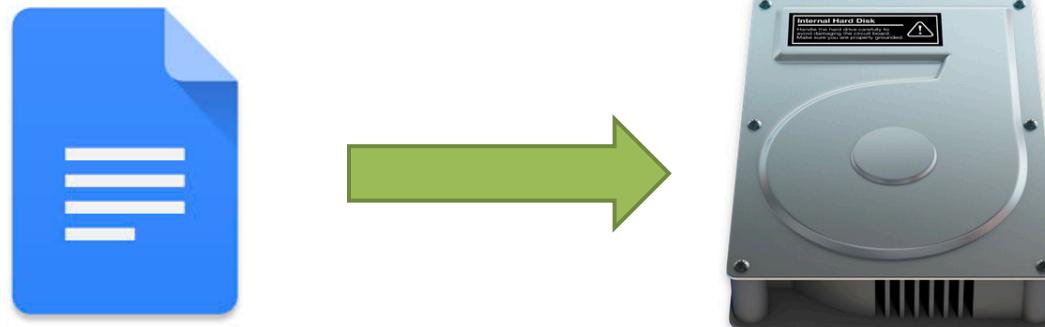
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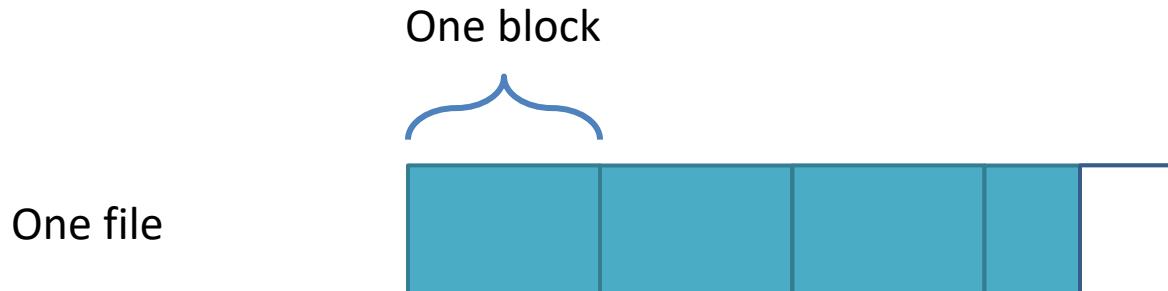
# Implementing Files on Disks

- Allocation: how to store the files on the disk?
  - Contiguous allocation
  - Linked list allocation
  - File allocation table (FAT)
  - Index allocation

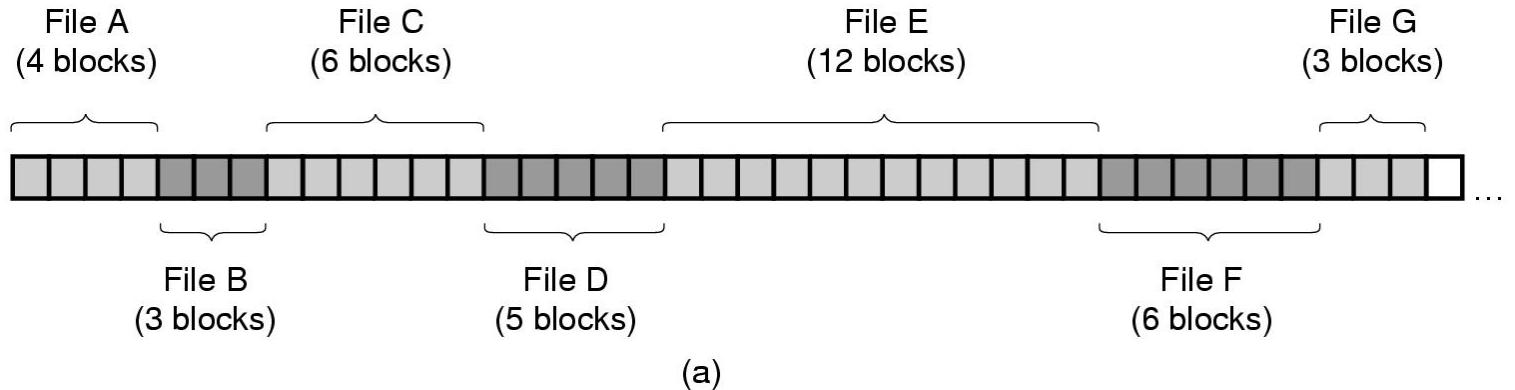


# Implementing Files (1) – Contiguous Allocation

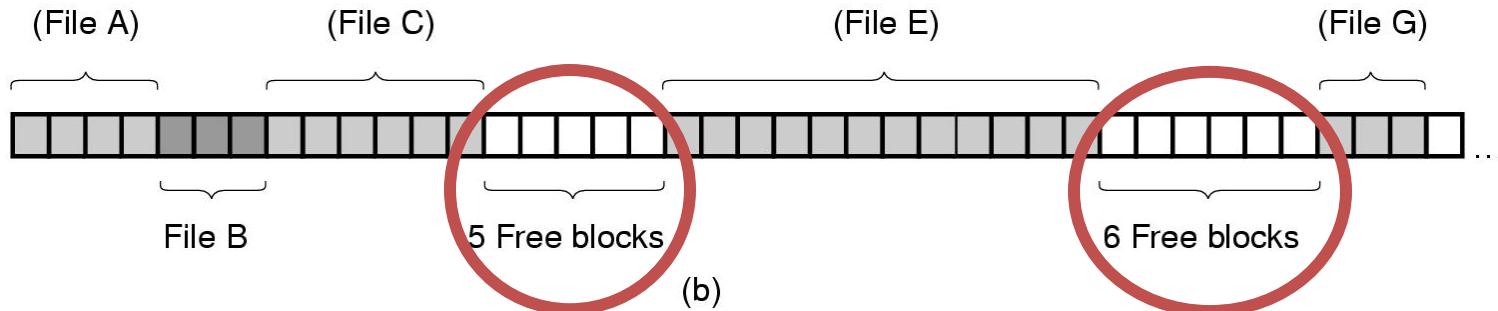
- **Contiguous Allocation:** each file is stored as a contiguous run of disk blocks.
- **Example:** On a disk with 1KB blocks, a 50KB file would be allocated 50 consecutive blocks. With 2KB blocks it would be 25 consecutive blocks.
- **Problem:** Each file begins at the start of a new block, so that if file A is occupying 3½ blocks, some space is wasted at the end of the last block.



# Implementing Files (1) – Contiguous Allocation



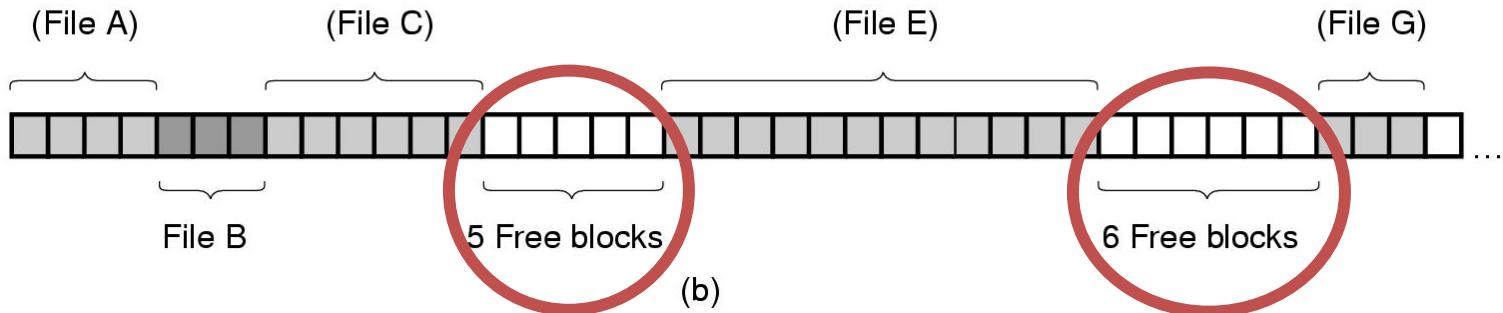
(a) Contiguous *block allocation* of disk space for 7 files



(b) State of the disk after files D and F have been dynamically removed

# Implementing Files (1) – Contiguous Allocation

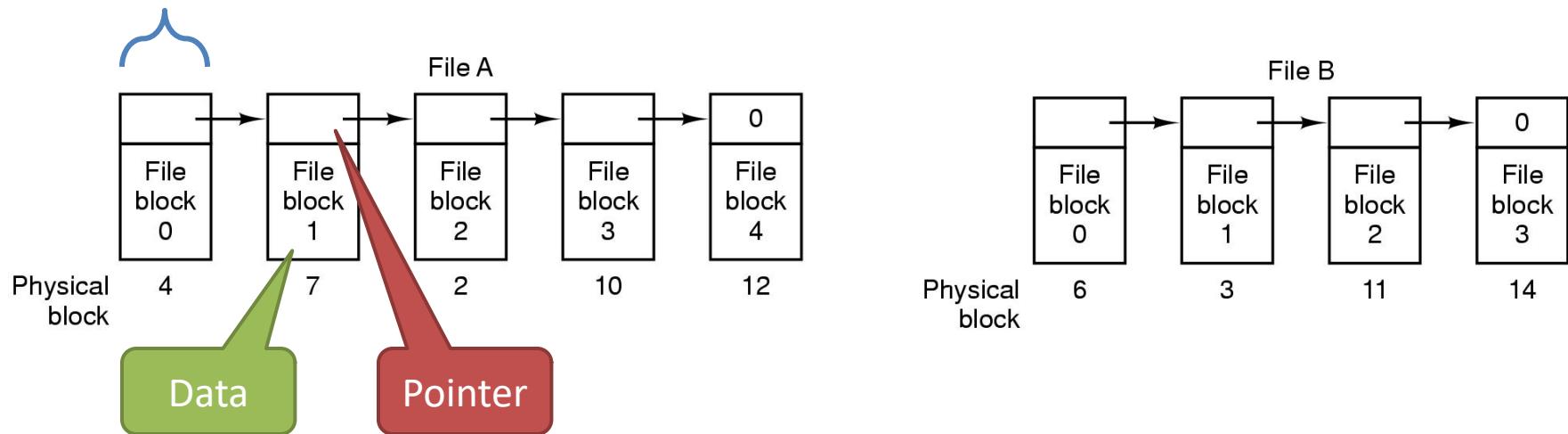
- **Advantages:**
  - Simple to implement.
  - The read performance is excellent because the entire file can be read from the disk in a single operation.
- **Drawbacks:**
  - Over the course of time the disk becomes **fragmented**.



# Implementing Files (2) – Linked List Allocation

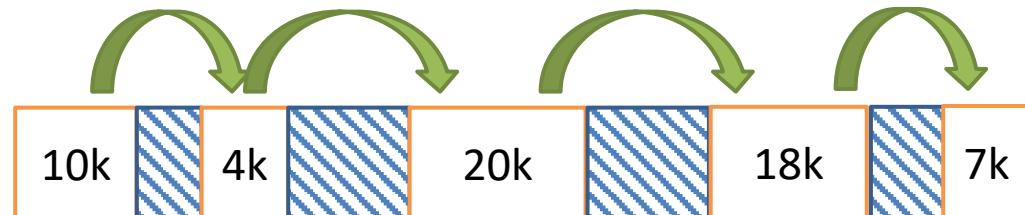
- Keep each file as a linked list of disk blocks
  - The first word of each block is used as a pointer to the next one.
  - The rest of the block is for data.

One block

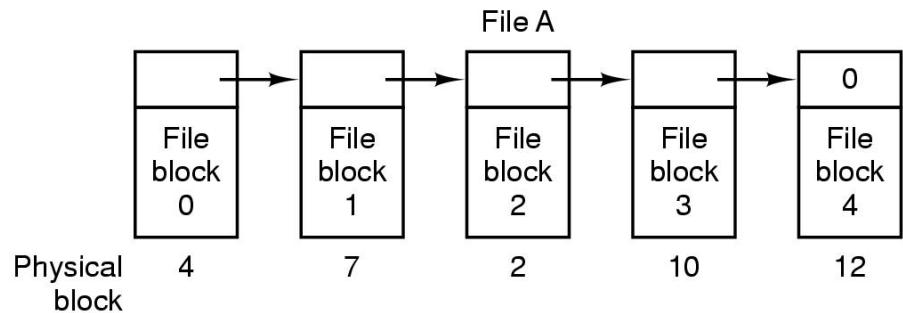


# Implementing Files (2) – Linked List Allocation

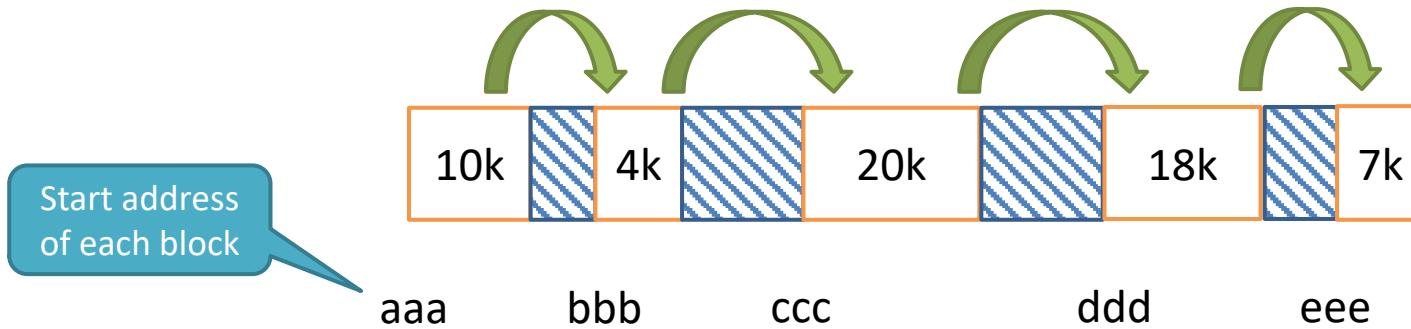
- Pros:
  - no space is lost due to disk fragmentation



- Cons:
  - random access of a file is very slow (because every time it has search from the start)



# Implementing Files (3) – FAT (File Allocation Table)



Block ID	address
1	aaa
2	bbb
3	ccc
4	ddd
5	eee

Memory

- FAT (File allocation table): a table in memory with the pointer word of each disk block

# Implementing Files (3) – FAT (File Allocation Table)

- **Advantages:**

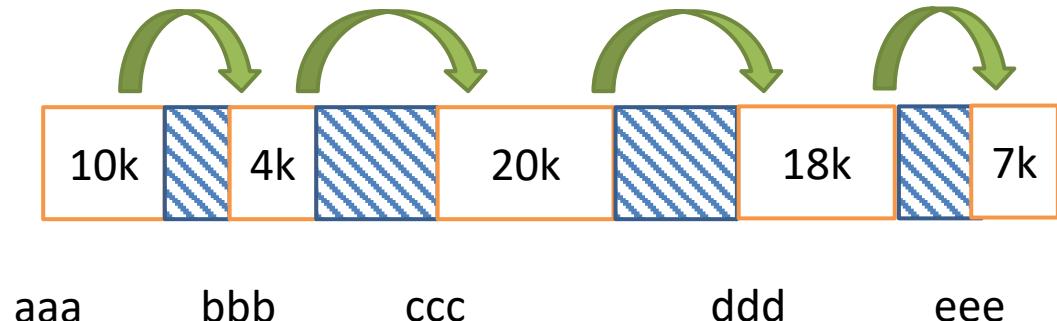
- Using FAT random access can be made much easier.

- **Drawbacks:**

- the entire table must be in memory all the time to make it work.

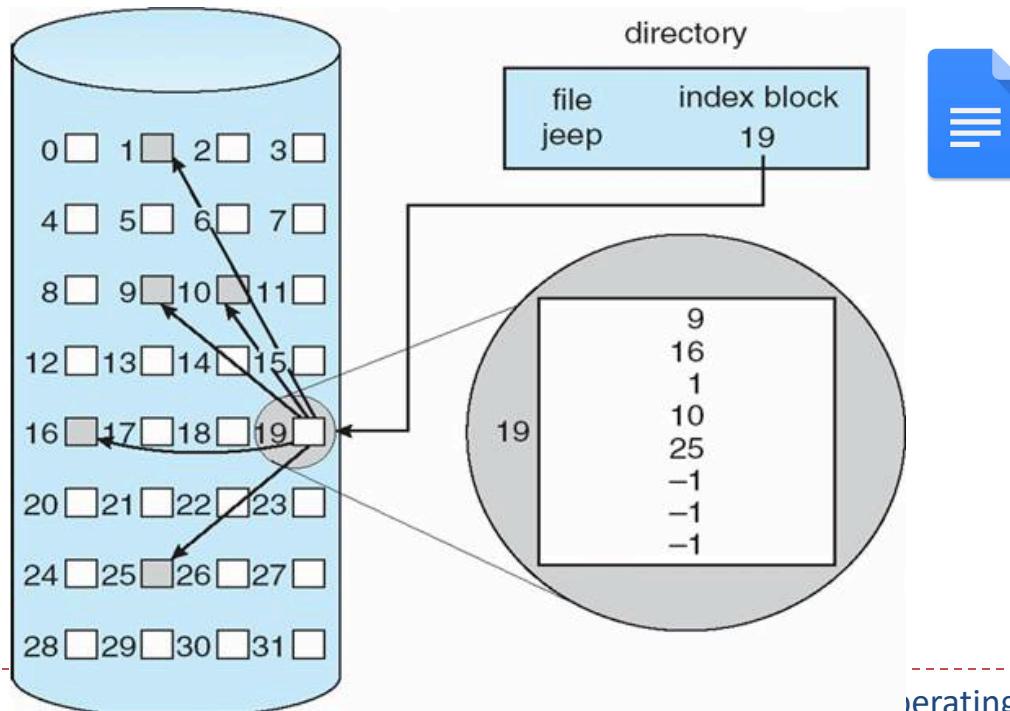
Memory

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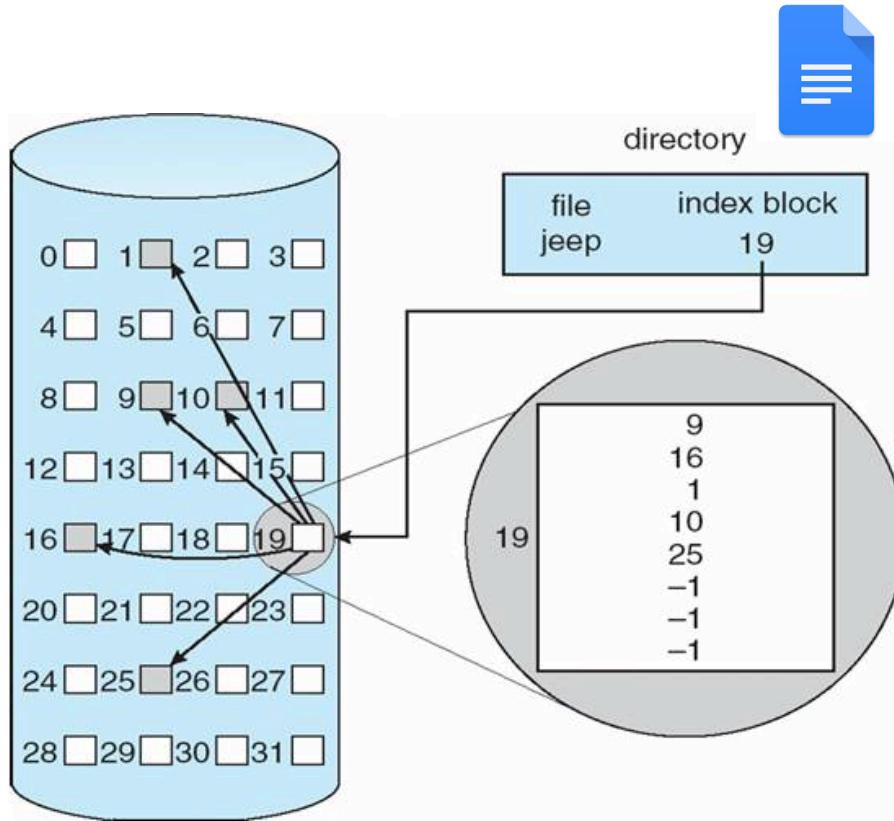


# Implementing Files (4) – Indexed Allocation

- Each file has its own ***index block*** on disk
- An index block grouping all pointers together (e.g., node 19)
- It contains an array of disk address



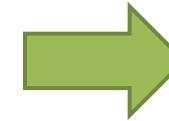
# Implementing Files (4) – Indexed Allocation



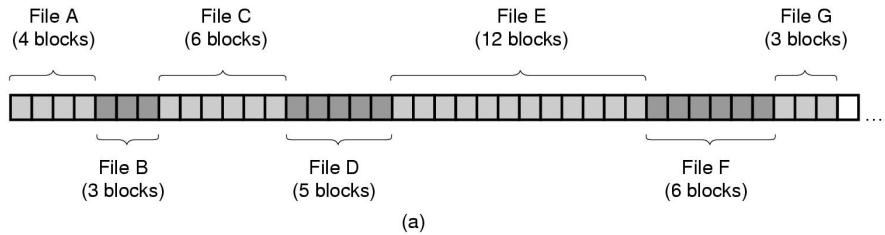
**i-node:** a data structure listing the attributes and disk addresses of the file's blocks

Unlike the FAT, the i-node is **in memory** only when the corresponding file is **open**.

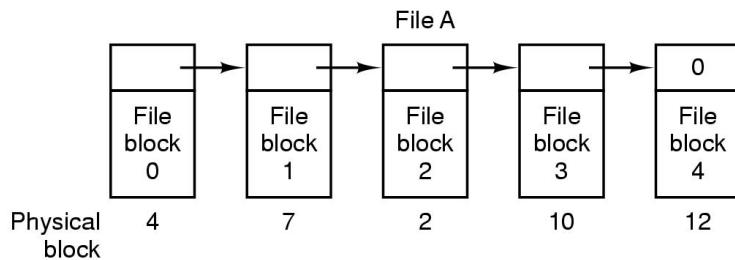
# Implementing Files – Summary



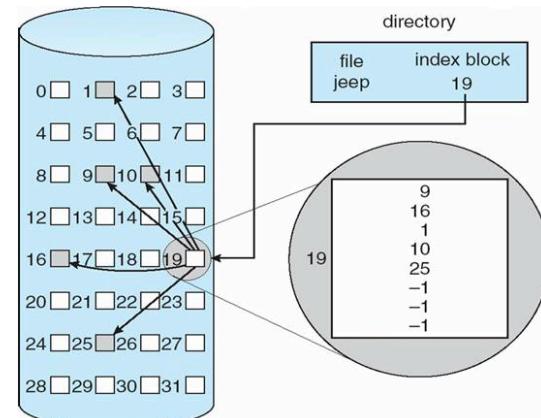
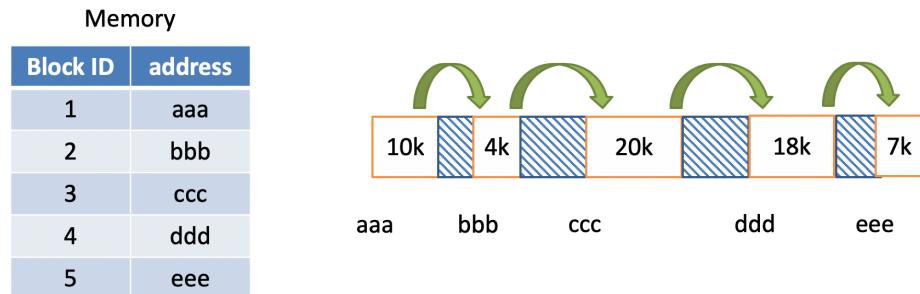
- How to store file on disk?
  - Contiguous allocation
  - Linked list allocation
  - File allocation table (FAT)
  - Index allocation



(a)



Physical block



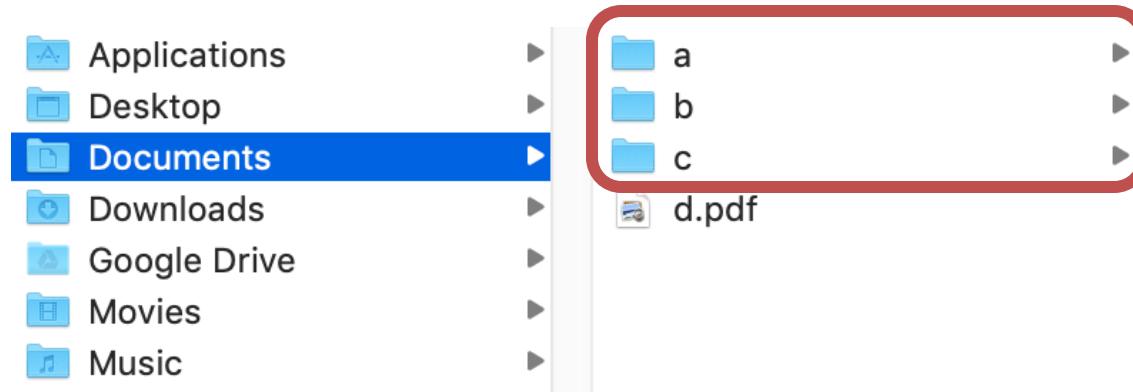
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# Implementing Directories

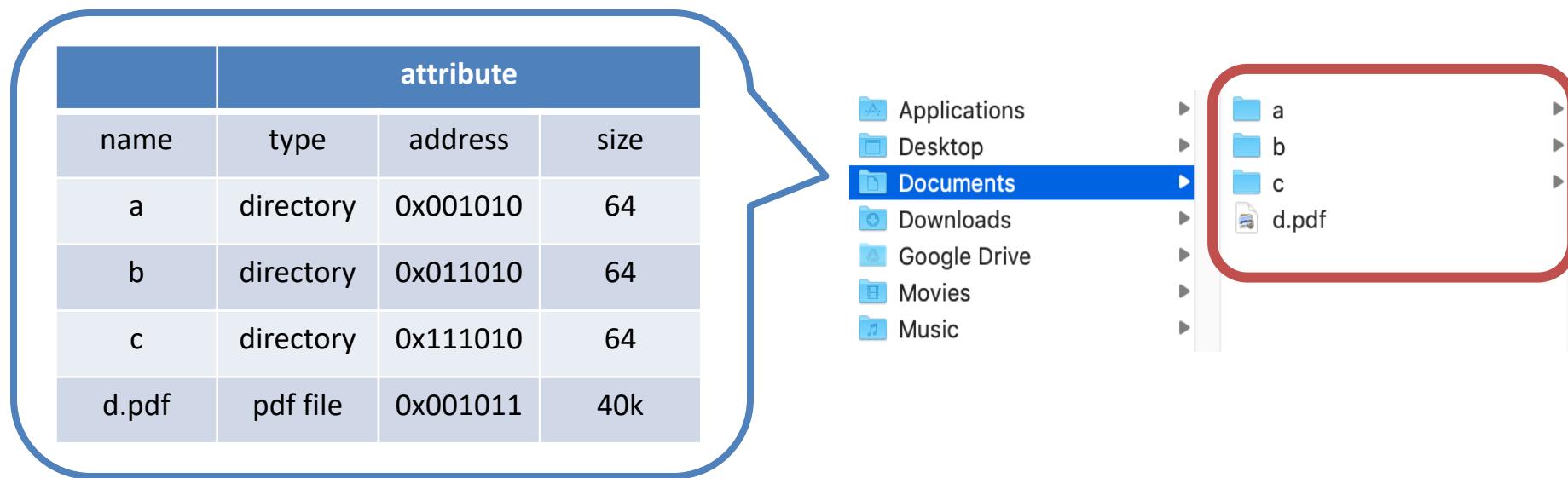


```
ksuo@ltksup50143mac ~/Documents> ls -al
total 104
drwx-----+ 8 ksuo  staff    256 Nov  5 16:20 .
drwxr-xr-x+ 32 ksuo  staff   1024 Nov  5 16:17 ..
-rw-r--r--@  1 ksuo  staff   6148 Nov  5 16:20 .DS_Store
-rw-------  1 ksuo  staff      0 Aug  5 09:21 .localized
drwxr-xr-x  2 ksuo  staff     64 Nov  5 16:19 a
drwxr-xr-x  2 ksuo  staff     64 Nov  5 16:20 b
drwxr-xr-x  2 ksuo  staff     64 Nov  5 16:20 c
-rw-r--r--@  1 ksuo  staff  42981 Nov  1 15:50 d.pdf
```

- The directory entry is a special file

# Implementing Directories Option 1

- In a simple design a directory consists of a list of fixed-size entries, one per file, containing
  - a (fixed-length) file name,
  - a structure of the file attributes, and
  - one or more disk addresses

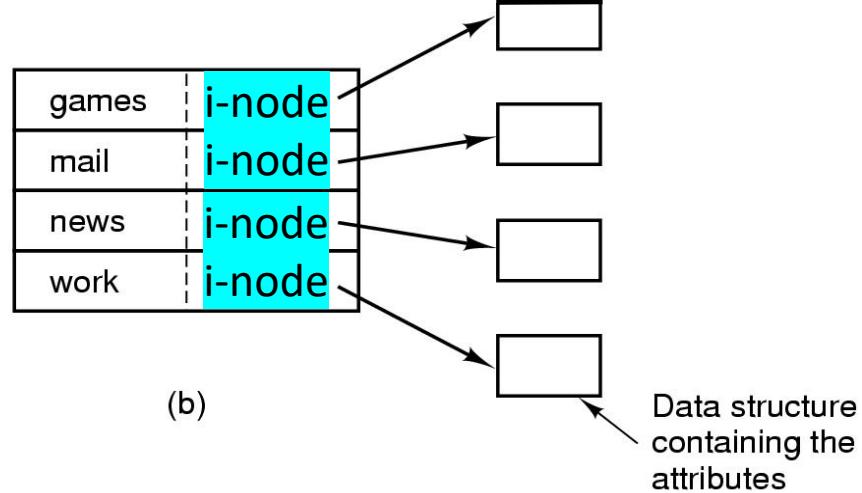


# Implementing Directories Option 2

- For systems that use i-nodes, another possibility for storing the attributes is in the **i-nodes**, rather than in the directory entries

games	attributes
mail	attributes
news	attributes
work	attributes

(a)



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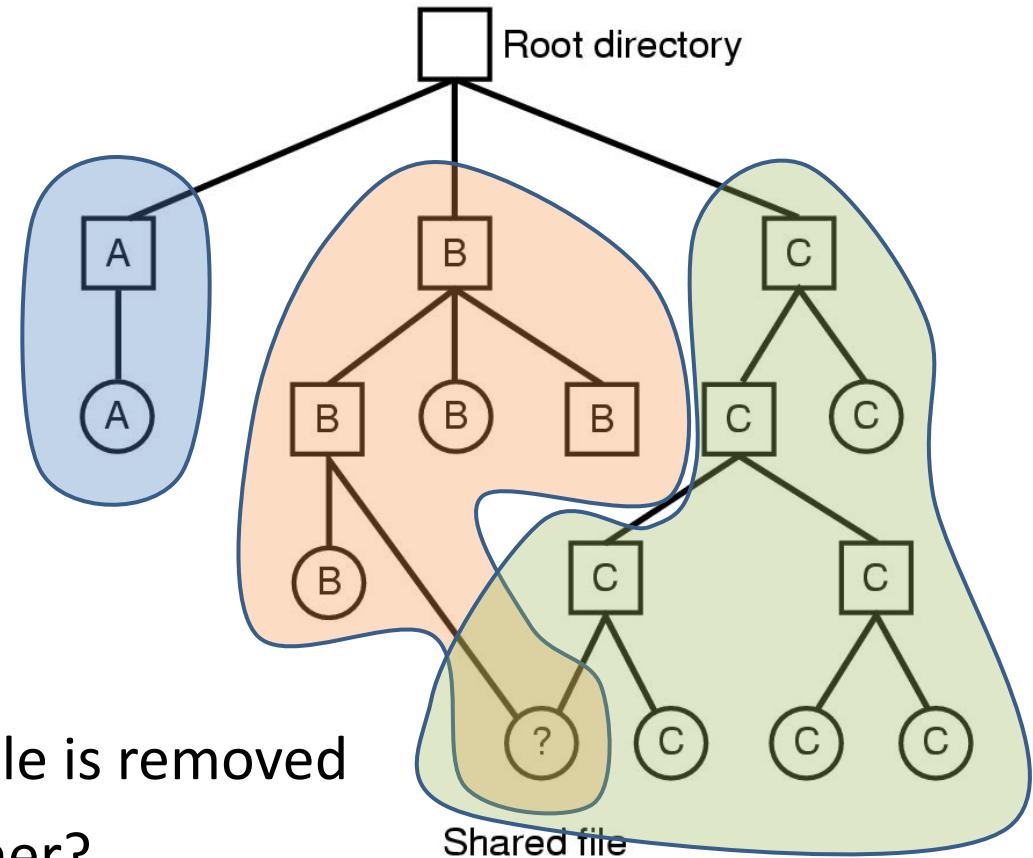


# Shared Files

File system containing a

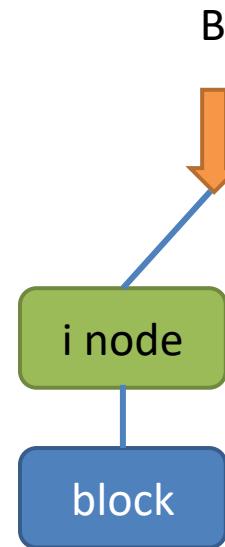
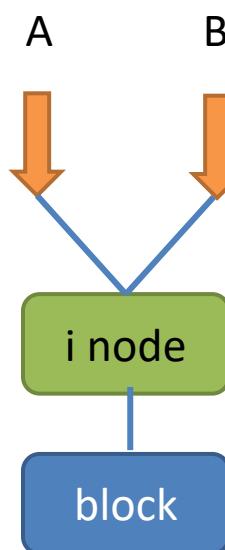
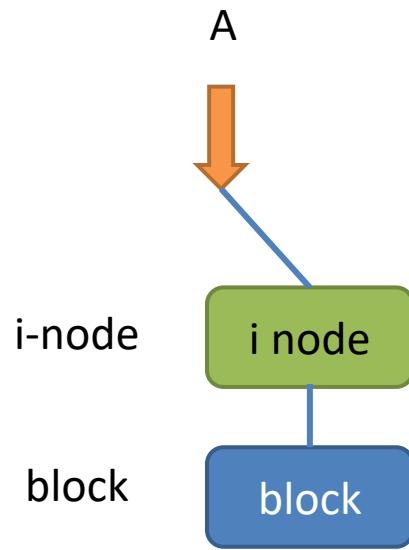
- Shared file is convenient for a file to appear simultaneously in different directories belonging to different users

shared file



What if a file is removed  
by the owner?

# Shared Files using i-node Hard Link

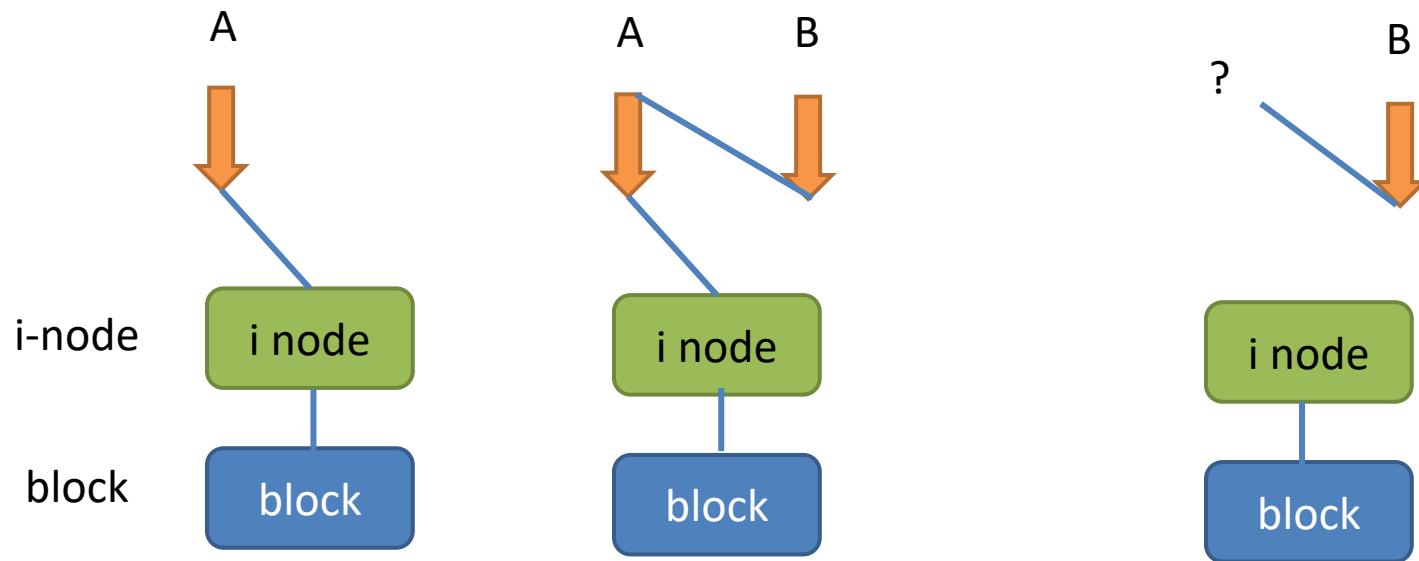


(a) Situation  
prior to  
linking;

(b) After the  
link is  
created

(c) After the original owner  
removes the file (the  
data is still there, just  
remove the link)

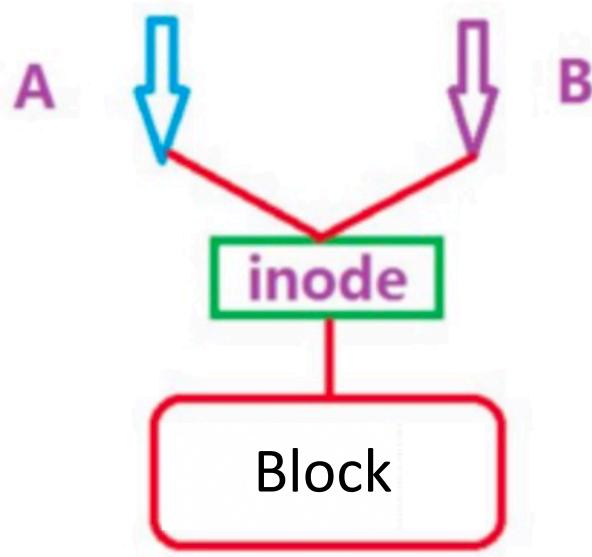
# Shared Files – Symbolic Link or Soft Link



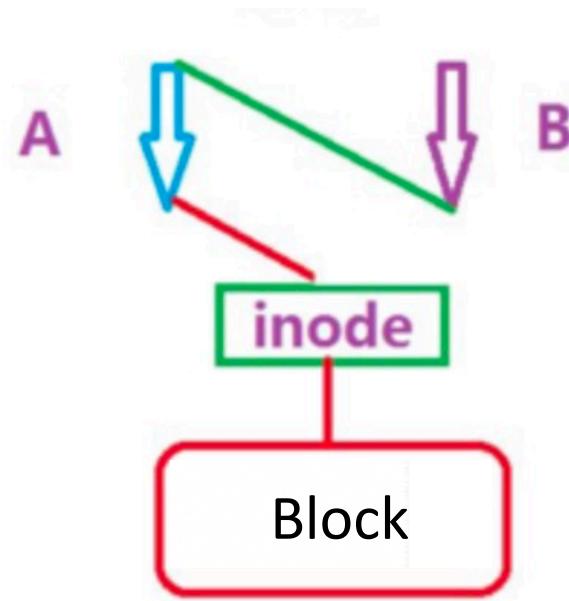
- A symbolic link is a special kind of file that points to another file. However, a symbolic link does not contain the data in the target file.

# Difference between hard link and soft link

Hard link



Soft link



# Hard link and soft link in Linux

---

- To create Hard link,
  - `ln <source> <linkname>`
- To create Symbolic link,
  - `ln -s <source> <linkname>`



# Hard link and soft link comparison

COMPARISON	HARD LINK	SOFT LINK
Definition	Hard link points to the original file	Soft link points to the hard link
I-node	Share the same inode pointing to the same file	Different inode pointing to the same file
Performance	Fast and efficient	Have some overhead due to longer path
Feature	Only link to a file	Link both to files and directory



# Outline

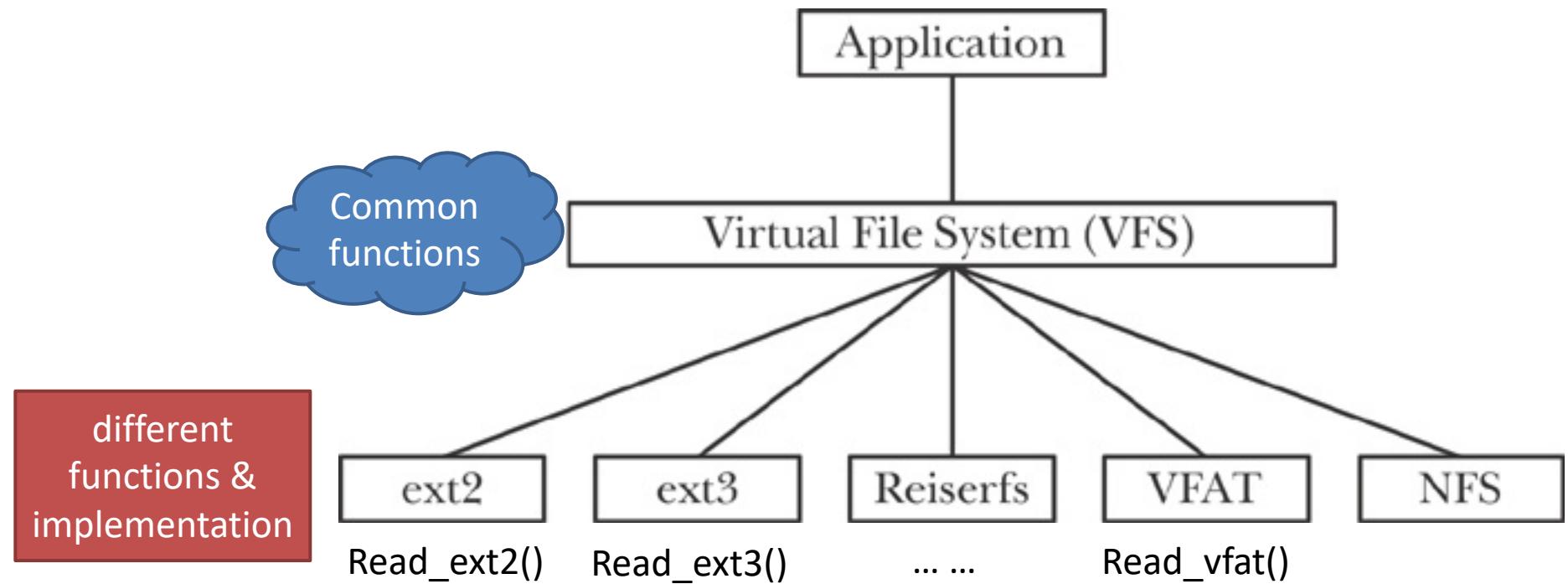
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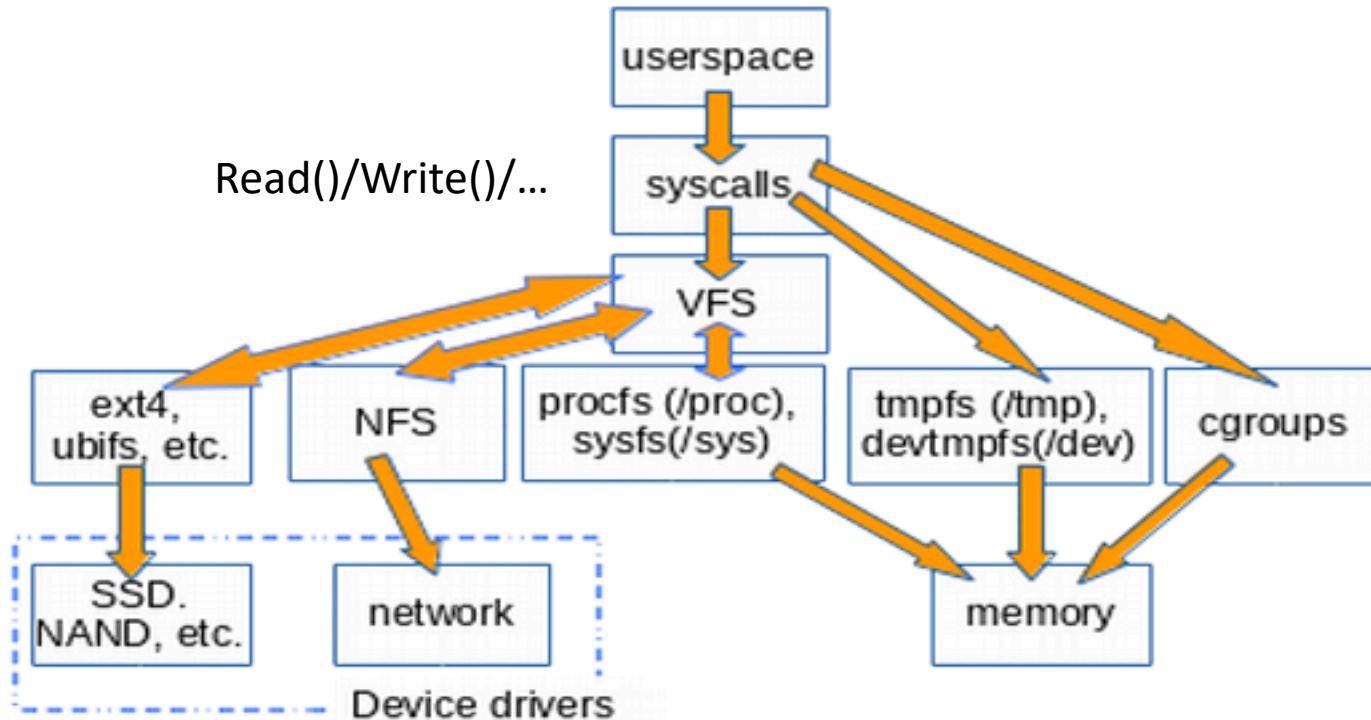
# Virtual File System (VFS)

- A **virtual file system** is an abstract layer with common functionalities supported by all the underlying concrete file systems



# Virtual File System (VFS)

- The key idea is to abstract out that part of the file system that is **common to all file systems** and put that code in a separate layer that calls the underlying concrete file system to actually manage the data. The apps interact with the VFS.



# Conclusion

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