CS 344: Operating Systems I
01.30: Files

M/W 12:00 – 1:50 PM (LINC #200)

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SAIL
Secure AI Systems Lab

Notice

- Announcements
  - PA I submissions we cannot compile

Notice

- Deadlines (~2 weeks)
  - (1/30 11:59 PM) Midterm quiz 1 – Today
  - (2/06 11:59 PM) Programming assignment 2
  - (2/13 11:59 PM) Midterm quiz 2

Preliminaries: UNIX and Linux

- *NIX: Operating Systems
  - UNIX (Paper)
    - 1969: The OS was developed by AT&T Bell Lab, written in assembly languages
    - 1972: C was developed by the same lab
      - "UNIX can run on hardware costing as little as $40,000" [1]

[1] The UNIX Time-Sharing System, *ACM SOSP* 1973

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      - "UNIX can run on hardware costing as little as $40,000" [1]
  - Linux
    - 1991: Open-source OS, developed by Linus Torvalds
      - Studied at the University of Helsinki
      - His master's thesis: "Linux: a Portable Operating System" (Thesis) [2]
        - ≫ "while the Linux project has been closely associated with me personally, partly due to the name, I'd like to make it very clear that the Linux OS is a huge project done co-operatively by lots of people all over the world … Thanks to all of you."

[1] The UNIX Time-Sharing System, *ACM SOSP* 1973
[2] Linux: a Portable Operating System, Linus Torvalds

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      - Linus Torvalds lives in **Oregon**

Preliminaries: *NIX vs. POSIX

- *NIX: Operating Systems
  - UNIX (Paper)
  - Linux (Thesis)

- POSIX: Portable Operating System Interface (for UniX)
  - OS standard specified by IEEE
  - Defines standard interfaces for system- and user-level APIs
  - Made the applications are portable between Unix-like OSes

[1] The UNIX Time-Sharing System, *ACM SOSP* 1973
[2] Linux: a Portable Operating System, Linus Torvalds

Topics for today

- Part II: Files and File System Basics
  - Provide abstractions
    - What is a file (and a directory)?
    - What is the access control/permission?
  - Offer standard interface
    - How do we create/read/write a file?
    - How do we modify access/permission?
  - Manage resources
    - How OS manages files (and directories)?

Provide abstraction: what is a file?

- File
  - **Definition:** a named collection of data (*e.g.*, movie.csv containing movie data)
  - **POSIX : a sequence of data bytes**
  - ***NIX OS : everything is a file**
    - Files on secondary storages, *e.g.*, disks
    - Devices (mouse, keyboard, monitor, …)
    - Network devices (network card, sockets in OS, …)
    - Inter-process communications (pipes, sockets, …)

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- Directories
  - **Definition : a folder containing files and directories**
  - **Motivation:**
    - Scenario: one day you create 100k+ files and the next day, you want to use them

Provide abstraction: what is a file?

- Directories
  - **Definition :** a folder containing files and directories
  - **Motivation:**
    - Scenario: one day you create 100k+ files and the next day, you want to use them
  - **Solution :**
    - **S0:** You are Von Neumann; remember all the files
    - **S1:** Your system creates a folder containing all the files for each user
    - **S2:** Your system creates multiple folders containing the same kinds

Provide abstraction: files and directories (in Linux)

os1 ~/lecture/CS344-OS1$ ls -lh

total 312K

Permission	# hard-link	owner	owner-group	size (b)	last modified	name
drwxrwx---.	6	sahong	upg1xxxx	186	Apr 10 22:14	.
drwxrwx---.	3	sahong	upg1xxxx	73	Apr 5 19:58	..
drwxrwx---.	2	sahong	upg1xxxx	95	Apr 5 19:58	bufferoverflow
drwxrwx---.	2	sahong	upg1xxxx	52	Apr 4 09:02	bufferoverrun
lrwxrwxrwx.	1	sahong	upg1xxxx	22	Apr 10 22:14	home -> /nfs/stak/users/hongsa
-rw-rw----.	1	sahong	upg1xxxx	44	Apr 4 08:15	README.md
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Provide abstraction: files and directories (in Linux)

os1 ~/lecture/CS344-OS1$ ls -alh

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drwxrwx---.	2	sahong	upg1xxxx	52	Apr 4 09:02	bufferoverrun
drwxrwx---.	8	sahong	upg1xxxx	299	Apr 10 21:56	.git
-rw-rw----.	1	sahong	upg1xxxx	430	Apr 5 19:56	.gitignore
lrwxrwxrwx.	1	sahong	upg1xxxx	22	Apr 10 22:14	home -> /nfs/stak/users/hongsa
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Hidden files!

Provide abstraction: access control (in Linux)

- Users and groups
  - **Users** : an account, tied to actual users or that exists for specific applications
    - Physical users: Alice, Bob, …
    - Accounts for applications: root (sudo), httpd (Apache), ec2-user (AWS), …
  - **Groups:** a logical expr of an organization, tying users together for a common purpose
    - Linux services: daemon, …

Provide abstraction: users and groups

os1 ~/lecture/CS344-OS1$ ls -alh

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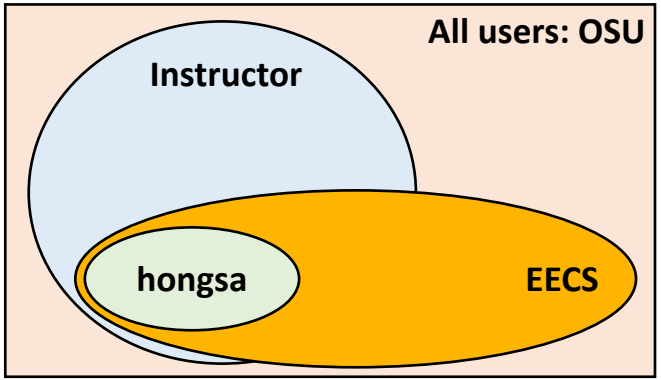
… <omit the entries>						
Permission	**# hard-link**	**owner**	**owner-group**	**size (b)**	**last modified**	**name**

- Linux controls the access to files or directories based on three categories:
  - **u**ser : owner of a file or a directory
  - **g**roup : the group where users are
  - **o**thers: all the other users



Provide abstraction: permission

- Permission
  - **Read** : one can read files and directories with ‘r’ permission
  - **Write** : one can write files and dirs. with ‘w’ permission
  - **Execute:** one can execute files and dirs. with ‘x’ permission

Provide abstraction: permission (in Linux)

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Permission	# hard-link	owner	owner-group	size (b)	last modified	name
	… <omit the entries>					
-rw-rw----.	1	sahong	upg1xxxx	44	Apr 4 08:15	README.md
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- Permission representation
  - drwxrwx---

[Type] d: directory, -: file

[User] the first three letters (rwx)
[Group] the second three letters (rwx)
[Others] the last three letters (---)

Provide abstraction: permission (in Linux)

os1 ~/lecture/CS344-OS1$ ls -alh

total 312K

	… <omit the entries>					
-rw-rw----.	1	sahong	upg1xxxx	44	Apr 4 08:15	README.md
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Permission	**# hard-link**	**owner**	**owner-group**	**size (b)**	**last modified**	**name**

- Permission representation
  - drwxrwx---:
    - 770
    - 111111000

Interpretation

- Decimal #: 1st (user), 2nd (group), 3rd (others)
  + ex. 770 : 7 (user), 7 (group), 0 (others)
- Each #: Binary number
  1st (read), 2nd (write), 3rd (execute)
  + ex. 7 : 111 (rwx)
  + ex. 6 : 110 (rw)
  + ex. 600 : 110 000 000 (your ssh key)

Topics for today

- Part II: Files and File System Basics
  - Provide abstractions
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  - Offer standard interface
    - How do we create/read/write a file?
    - How do we modify access/permission?
  - Manage resources
    - How OS manages files (and directories)?

Offer standard interface: system calls

- System call
  - **Definition:** a user-level function call to request a service from the OS
  - **Example:** when we run a program "exec(<a program file>)"

- Two ways to use a system call
  - **Terminal:** run a command (that is a system call)
  - **C** : call a system call function
  - **Example**: run "exec" in Terminal or use "exec(<a program file>)" function in C

Offer standard interface: users and groups

- System calls (in Terminal)
  - Print the user and group IDs : "exec"
  - Create/modify/delete users : "useradd" / "usermod" / "userdel"
  - Create/modify/delete groups: "groupadd" / "groupmod" / "groupdel"

- System calls (in C)
  - Print the user and group IDs : "getuid()" / "getgid()"
  - Create/modify/delete users : No C APIs; we can use "system('useradd …')"
  - Create/modify/delete groups: No C APIs; we can use "system('groupadd …')"

Offer standard interface: users and groups

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Permission	**# hard-link**	**owner**	**owner-group**	**size (b)**	**last modified**	**name**

- An example of 'id' system call

os1 ~/lecture/CS344-OS1$ id

uid=1xxxxx (sahong) — **My user ID**

gid=4xxxx (upg1xxxx) — **My group ID**

groups=4xxxx (upg1xxxx), 3xxx (cs-faculty) — **Groups that I am associated with**

Offer standard interface: permission

- System calls (in Terminal)
  - Change the ownership : “chown -R <user>:<group>”
  - Change the permission: “chmod -R <mode to set>”

- System calls (in C)
  - Change the ownership : “chown(const char *_path_, uid_t _owner_, gid_t _group_)”
  - Change the permission: “chmod(const char *_pathname_, mode_t _mode_)”

Revisit: path (in Linux)

- Two types of paths
  - **Absolute path:** a complete file/dir path from the root '/'
  - **Relative path :** a file/dir path relative from my current working dir 'cwd'

- Examples:
  - **Absolute path:**
    - '/nfs/stak/users/sahong/example' (that you can get from 'pwd' command)
  - **Relative path :**
    - './example_program'
    - Absolute path for this file: '/nfs/stak/users/sahong/example/example_program'
    - **Q1:** If we move to '/nfs/stak' what's its relative path?
    - **Q2:** If we move to HOME ('~/') what's its relative path?

Revisit: path (in Linux)

- Useful programming practices
  - 1) Suppose that a program will be used by multiple users.
  - 2) Suppose that the program needs to read a common configuration file.
  - 3) Suppose that a user who runs the program asks to read their file.

Scenario 1) Absolute path.

A developer should put the program binary file (e.g., git) to a common location and users should use the absolute path to run this program in their shell.

Scenario 2) Both will be fine.

As a developer will use the same path for everyone, one can use an absolute path or a relative path from the program binary file.

Scenario 3) Relative path.

As the file shouldn't be read by any other users, the file will be located under a user's home dir. So, we can use a relative path from our home '~/' to the file.

Offer standard interface: permission

os1 ~/lecture/CS344-OS1$ ls -alh

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- Examples of "chown" and "chmod" commands
  - $ chown -R <someone>:<upg1xxxx> thread
  - $ chmod 644 README.md
  - $ chmod o+rw README.md
  - $ chmod 700 thread
  - $ chmod g-rwx thread

Rules
- Use a number, e.g., 644
- Use a string: user/group/others +/- perm.
  + ex. u+x (user can execute the file/dir)
  + ex. g-wx (group cannot write or execute it)

Offer standard interface: some useful system calls

- System calls (frequently used)
  - Get the details about a file : $ stat <file/dir name>
  - Create an empty file : $ touch <file/dir name>
  - Total size of a directory : $ du -alh <file/dir name>
  - Total filesystem size and info : $ df -h

    …

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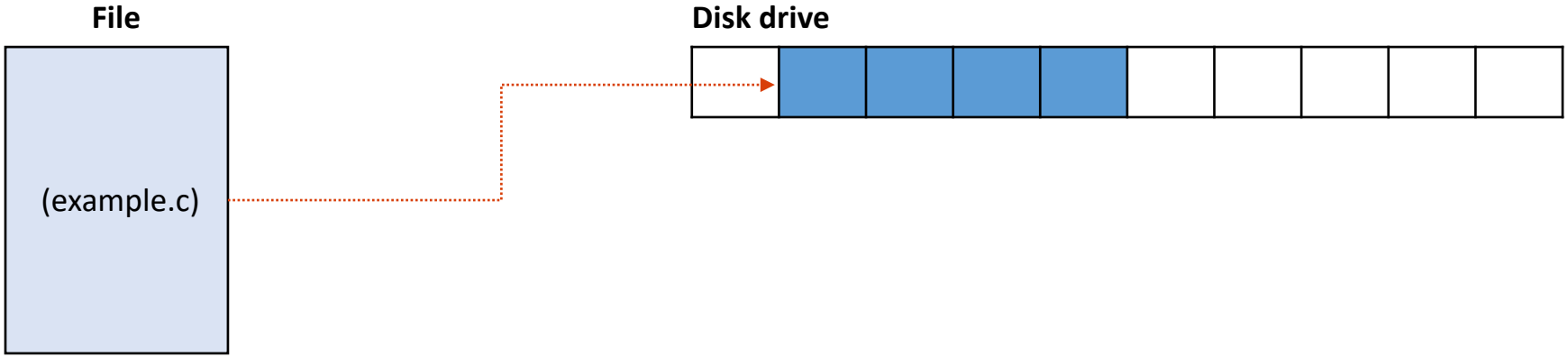
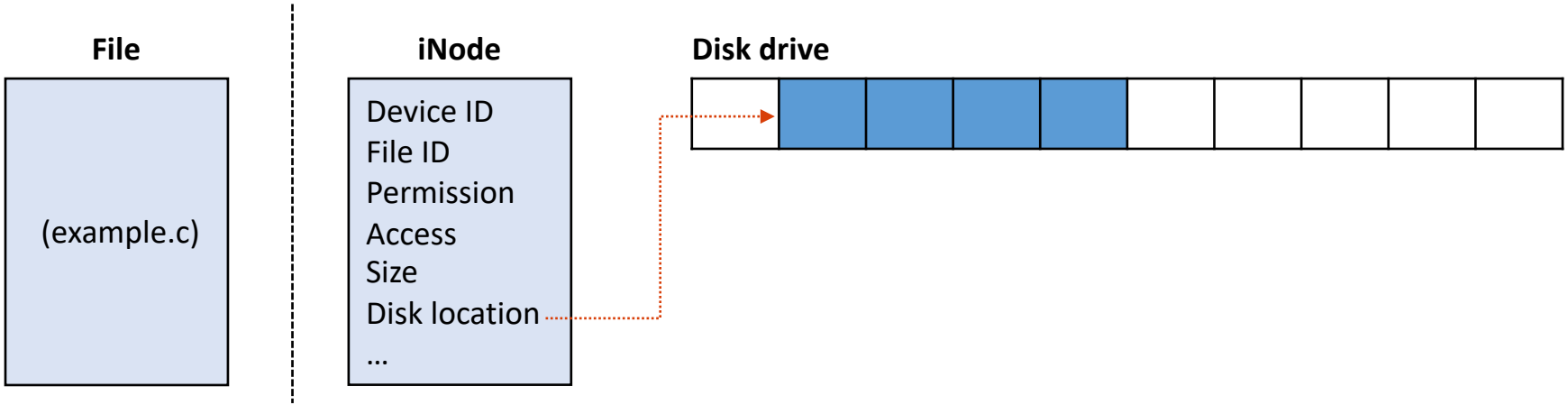
Problem: how to store files to storage

- Scenario 1: store a file to a disk drive
  - File: a sequence of data



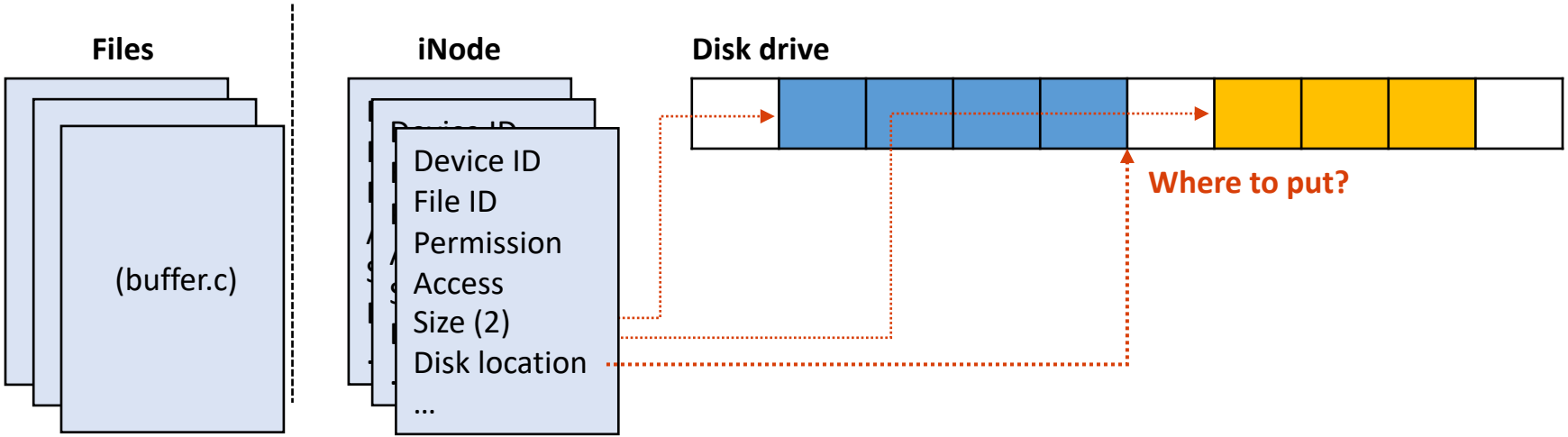
Manage resources: inode structure

- Scenario 1: store a file to a disk drive
  - **i(ndex)Node:** a data-structure that describes a file-system object, e.g., a file/dir.



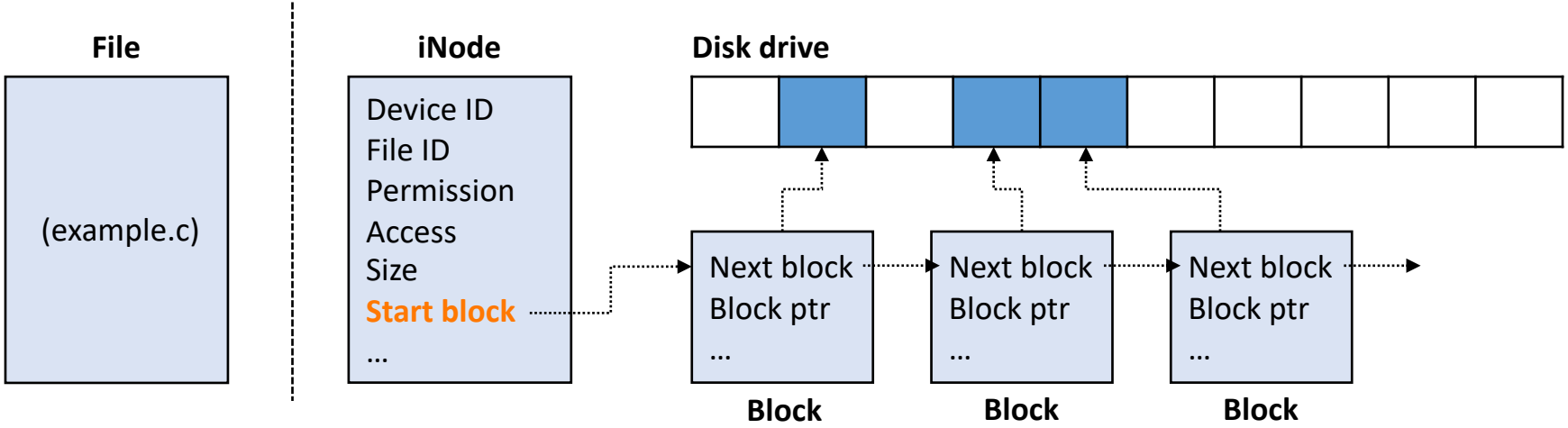
Manage resources: inode structure – cont'd

- Scenario 2: store **multiple (> 2+)** files to a disk drive
  - **i(ndex)Node:** a data-structure that describes a file-system object, e.g., a file/dir.



Manage resources: block structure

- Scenario 2: store **multiple (> 2+)** files to a disk drive
  - **i(ndex)Node:** a data-structure that describes a file-system object, e.g., a file/dir.
  - **Block** : a small(est) unit of data storage, defined by OS



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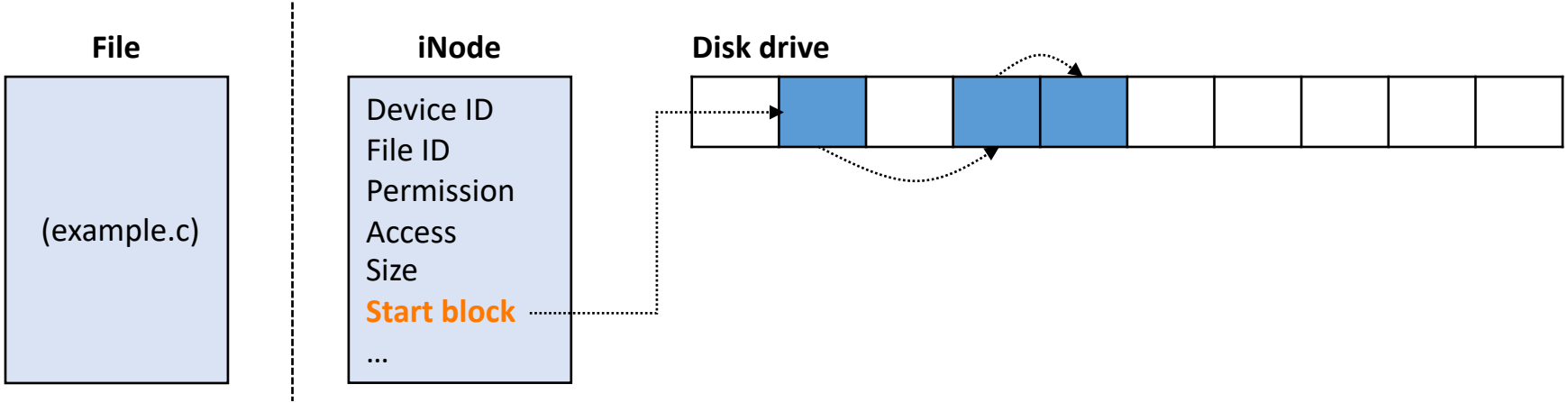

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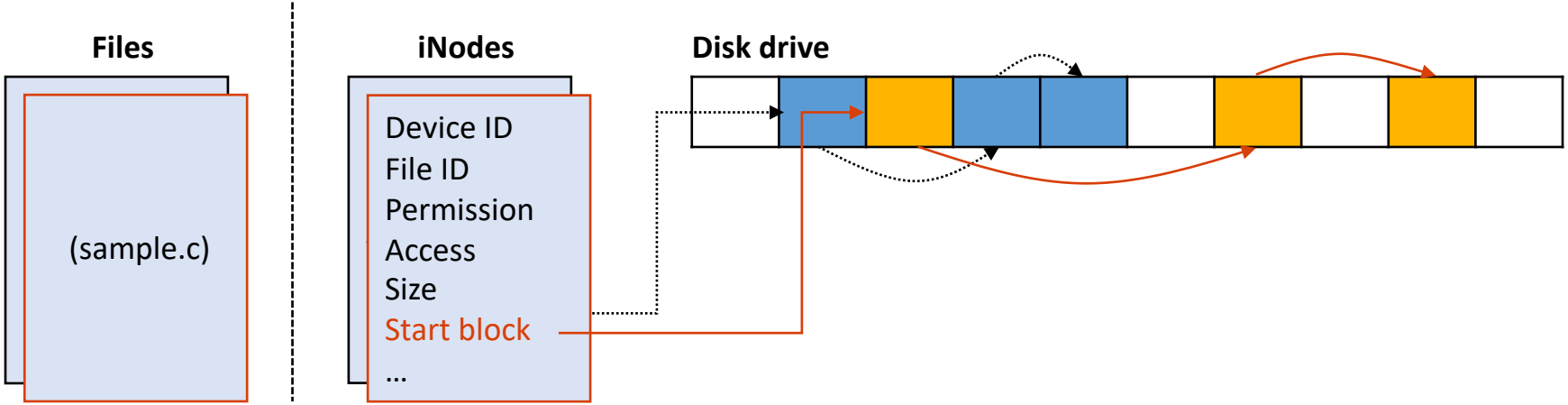

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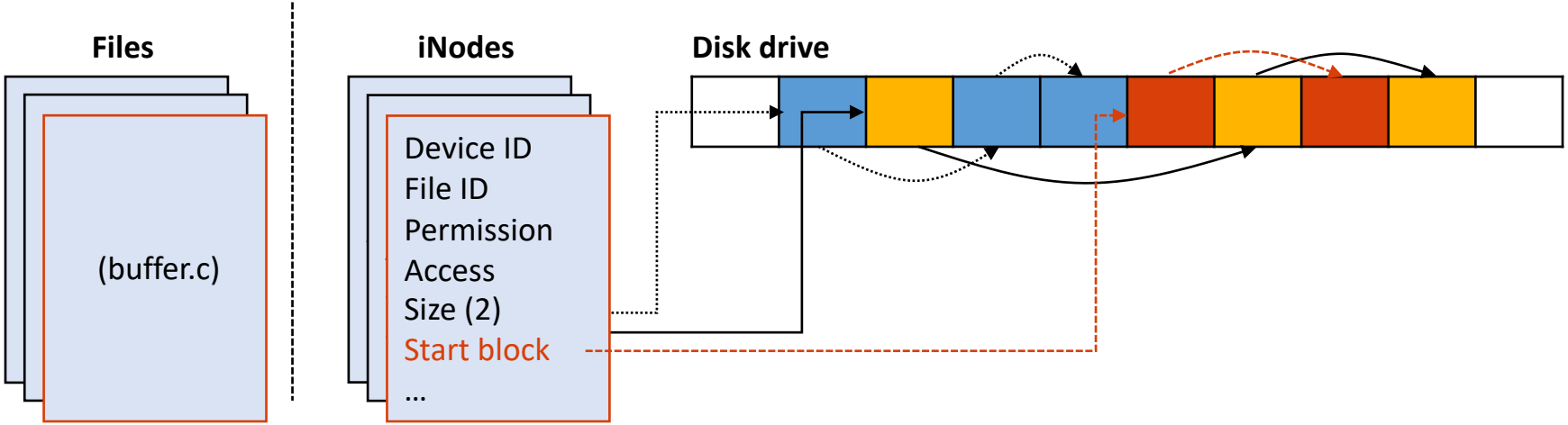

MANAGE RESOURCES: BLOCK STRUCTURE FOR *EFFICIENCY*

- Scenario 3: Users access a certain block(s)
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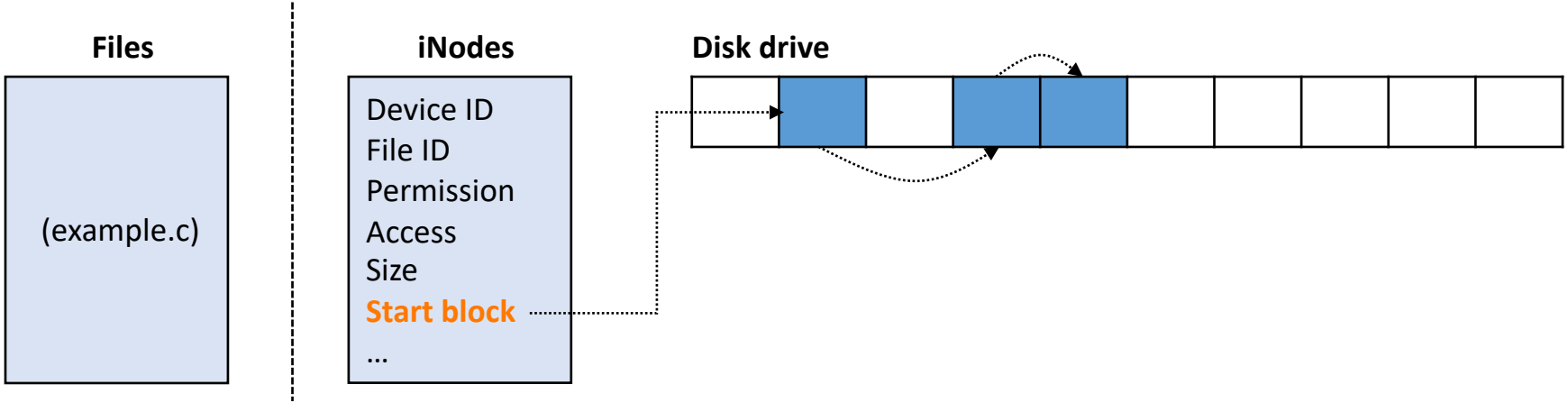

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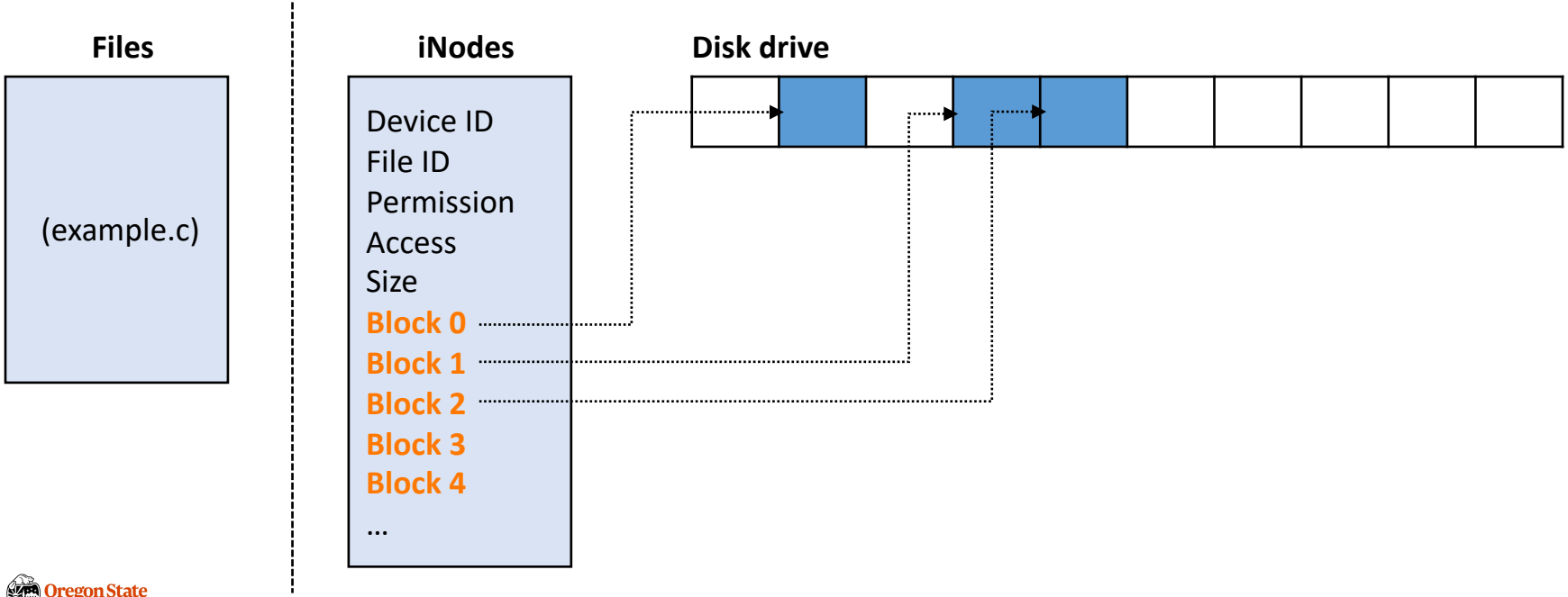
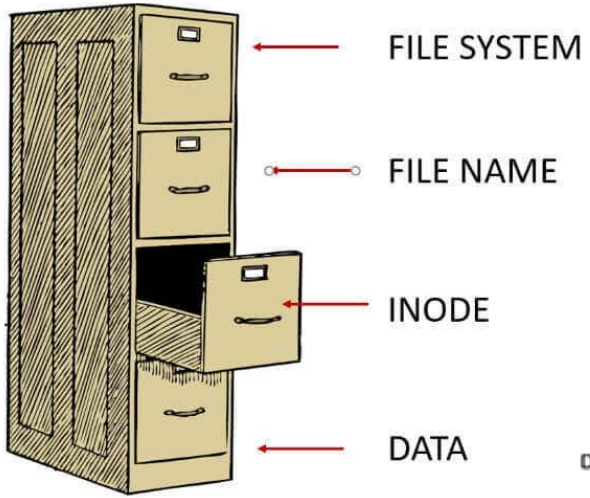
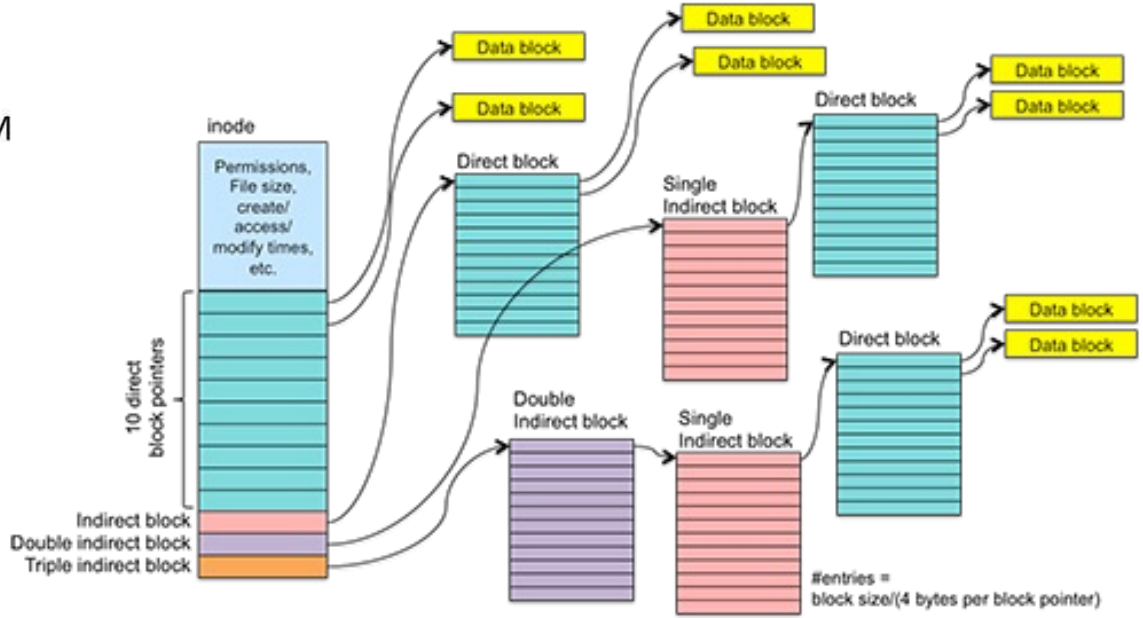


Manage resources: filesystem structure overview





[1] What Are inodes in Linux and How Are They Used? https://helpdeskgeek.com/linux-tips/what-are-inodes-in-linux-and-how-are-they-used/
[2] File System Design Case Studies, https://people.cs.rutgers.edu/~pxk/416/notes/13-fs-studies.html

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SAIL

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