

CSGE602055 Operating Systems

CSF2600505 Sistem Operasi

Week 03: File System & FUSE

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<https://os.vlsm.org/Slides/os03.pdf>

Always check for the latest revision!

REV341 05-Sep-2021

OS212⁴): Operating Systems 2021 - 2

| OS A | OS B | OS C | OS INT |
|--|---|---|---|
| Every first day of the Week, Quiz#1 and Quiz#2 : 07:15-08:00 | | | |
| Monday/Thursday 13:00 — 14:40 14:00 — finish | Monday/Thursday 15:00 — 16:40 ¹ 16:00 — finish | Monday/Thursday 13:00 — 14:40 13:00 — 14:40 | Monday/Wednesday 08:00 — 09:40 09:00 — finish |

| Week | Schedule & Deadline ²⁾ | Topic | OSC10 ³⁾ |
|---------|-----------------------------------|--|---------------------|
| Week 00 | 30 Aug - 05 Sep 2021 | Overview 1, Virtualization & Scripting | Ch. 1, 2, 18. |
| Week 01 | 06 Sep - 12 Sep 2021 | Overview 2, Virtualization & Scripting | Ch. 1, 2, 18. |
| Week 02 | 13 Sep - 19 Sep 2021 | Security, Protection, Privacy, & C-language. | Ch. 16, 17. |
| Week 03 | 20 Sep - 26 Sep 2021 | File System & FUSE | Ch. 13, 14, 15. |
| Week 04 | 27 Sep - 03 Oct 2021 | Addressing, Shared Lib, & Pointer | Ch. 9. |
| Week 05 | 04 Oct - 10 Oct 2021 | Virtual Memory | Ch. 10. |
| Week 06 | 11 Oct - 17 Oct 2021 | Concurrency: Processes & Threads | Ch. 3, 4. |
| Week 07 | 01 Nov - 07 Nov 2021 | Synchronization & Deadlock | Ch. 6, 7, 8. |
| Week 08 | 08 Nov - 14 Nov 2021 | Scheduling + W06/W07 | Ch. 5. |
| Week 09 | 15 Nov - 21 Nov 2021 | Storage, Firmware, Bootloader, & Systemd | Ch. 11. |
| Week 10 | 22 Nov - 28 Nov 2021 | I/O & Programming | Ch. 12. |

¹⁾ **OS B**: Week00-Week05 (RMS); Week06-Week10 (MAM).

²⁾ The **DEADLINE** of Week 00 is 05 Sep 2021, whereas the **DEADLINE** of Week 01 is 12 Sep 2021, and so on...

³⁾ Silberschatz et. al.: **Operating System Concepts**, 10th Edition, 2018.

⁴⁾ This information will be on **EVERY** page two (2) of this course material.

STARTING POINT — <https://os.vlsm.org/>

- ❑ **Text Book** — Any recent/decent OS book. Eg. (**OSC10**) Silberschatz et. al.: **Operating System Concepts**, 10th Edition, 2018. See also <https://www.os-book.com/OS10/>.
- ❑ **Resources**
 - ❑ **SCELE OS212** — <https://scele.cs.ui.ac.id/course/view.php?id=3268>.
The enrollment key is **XXX**.
 - ❑ **Download Slides and Demos from GitHub.com**
<https://github.com/UI-FASILKOM-OS/SistemOperasi/>:
[os00.pdf \(W00\)](#), [os01.pdf \(W01\)](#), [os02.pdf \(W02\)](#), [os03.pdf \(W03\)](#),
[os04.pdf \(W04\)](#), [os05.pdf \(W05\)](#), [os06.pdf \(W06\)](#), [os07.pdf \(W07\)](#),
[os08.pdf \(W08\)](#), [os09.pdf \(W09\)](#), [os10.pdf \(W10\)](#).
 - ❑ **Problems**
[195.pdf \(W00\)](#), [196.pdf \(W01\)](#), [197.pdf \(W02\)](#), [198.pdf \(W03\)](#),
[199.pdf \(W04\)](#), [200.pdf \(W05\)](#), [201.pdf \(W06\)](#), [202.pdf \(W07\)](#),
[203.pdf \(W08\)](#), [204.pdf \(W09\)](#), [205.pdf \(W10\)](#).
 - ❑ **LFS** — <http://www.linuxfromscratch.org/lfs/view/stable/>
 - ❑ **OSP4DISS** — <https://osp4diss.vlsm.org/>
 - ❑ **DOIT** — <https://doit.vlsm.org/001.html>

Agenda

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Week 03 File System & FUSE: Topics¹

- Files: data, metadata, operations, organization, buffering, sequential, nonsequential
- Directories: contents and structure
- File systems: partitioning, mount/unmount, virtual file systems
- Standard implementation techniques
- Memory-mapped files
- Special-purpose file systems
- Naming, searching, access, backups
- Journaling and log-structured file systems

¹Source: ACM IEEE CS Curricula 2013

Week 03 File System & FUSE: Learning Outcomes¹

- Describe the choices to be made in designing file systems.
[Familiarity]
- Compare and contrast different approaches to file organization, recognizing the strengths and weaknesses of each. [Usage]
- Summarize how hardware developments have led to changes in the priorities for the design and the management of file systems.
[Familiarity]
- Summarize the use of journaling and how log-structured file systems enhance fault tolerance. [Familiarity]

¹Source: ACM IEEE CS Curricula 2013

File System Interface

- File Concept

- File Attributes: Name, Id, Type, Location, Size, Protection, Time Stamp: create, last modified, last accessed.
- File Operation
 - Create/Delete/Truncate
 - Open/Close
 - Read/Write
- File Types: Executable, Object, Source Code, Library, Markup, Markdown, Archive, Compressed.
- File Structure: No Structure (just a string).
- Access Methods: Sequential vs Direct Access

- Directory and Disk Structure

- Three-Structured Directories
- Directory Operation: create/delete, search/list, rename, traverse
- Path Name: Absolute vs. Relative
- FS Mounting vs. Volume Based System

- File Sharing

- Protection: Access Control (eg. -rwx-x-x)

File System Organization

- Disk Partition
 - One Disk — Many Partitions
 - Many Disks — One Partitions
 - Many Disks — Many Partitions
 - One Partition — One File System (Volume)
- Mounting vs. Volumes

```
demo@badak:~$ df
```

| Filesystem | 1K-blocks | Used | Available | Use% | Mounted on |
|------------|-----------|----------|-----------|------|----------------|
| /dev/sda2 | 9515660 | 1435776 | 7573468 | 16% | / |
| /dev/sdb1 | 32895760 | 12156672 | 19045036 | 39% | /usr |
| /dev/sdc1 | 412322216 | 79695252 | 311639116 | 21% | /home |
| udev | 10240 | 0 | 10240 | 0% | /dev |
| tmpfs | 16508828 | 0 | 16508828 | 0% | /dev/shm |
| tmpfs | 6603532 | 8880 | 6594652 | 1% | /run |
| tmpfs | 5120 | 0 | 5120 | 0% | /run/lock |
| tmpfs | 16508828 | 0 | 16508828 | 0% | /sys/fs/cgroup |
| tmpfs | 3301768 | 0 | 3301768 | 0% | /run/user/1002 |

```
demo@badak:~$
```


FHS: Filesystem Hierarchy Standard

- Source (URL) http://refspecs.linuxfoundation.org/FHS_3.0/fhs-3.0.pdf
- A file placement guidelines/requirements for GNU/Linux-like OS.

| FILES | shareable (multiple hosts) | unshareable (single hosts) |
|---------------------------------------|----------------------------|----------------------------|
| static (read only, except for update) | /usr, /opt | /etc, /boot |
| variable (r/w) | /var/mail, /var/spool/news | /var/run, /var/lock |

● The Root File System (Required)

| Directory | Description |
|-----------|---|
| /bin | Essential command binaries |
| /boot | Static files of the boot loader |
| /dev | Device files |
| /etc | Host-specific system configuration |
| /lib | Essential shared libraries and kernel modules |
| /media | Mount point for removable media |
| /mnt | Mount point for mounting a filesystem temporarily |
| /opt | Add-on application software packages |
| /run | Data relevant to running processes |
| /sbin | Essential system binaries |
| /srv | Data for services provided by this system |
| /tmp | Temporary files |
| /usr | Secondary hierarchy |
| /var | Variable data |

• Specific Options

| Directory | Description |
|------------|---|
| /home | User home directories (optional) |
| /lib<qual> | Alternate format essential shared libraries(optional) |
| /root | Home directory for the root user (optional) |

• The /usr Hierarchy

| Directory | Description |
|----------------|---|
| /usr/bin | Most user commands (required) |
| /usr/lib | Libraries (required) |
| /usr/local | Local hierarchy (empty after main installation) (required) /usr/local/{bin etc games include lib man sbin share src} (required) |
| /usr/sbin | Non-vital system binaries (required) |
| /usr/share | Architecture-independent data (required) /usr/share/{man misc} (required) /usr/share/{color dict doc games info locale} (optional) /usr/share/{nls ppd sgml terminfo tmac xml zoneinfo} (optional) |
| /usr/games | Games and educational binaries (optional) |
| /usr/include | Header files included by C programs (optional) |
| /usr/libexec | Binaries run by other programs (optional) |
| /usr/lib<qual> | Alternate Format Libraries (optional) |
| /usr/src | Source code (optional) |

• The /var Hierarchy

| Directory | Description |
|---------------|---|
| /var/cache | Application cache data (required) |
| /var/lib | Variable state information (required) /var/lib/misc (required) |
| /var/local | Variable data for /usr/local (required) |
| /var/lock | Lock fileslogLog files and directories (required) |
| /var/opt | Variable data for /opt (required) |
| /var/run | Data relevant to running processes (required) |
| /var/spool | Application spool data (required) |
| /var/tmp | Temporary files preserved between system reboots (required) |
| /var/backups | (reserved names, do not use) |
| /var/cron | (reserved names, do not use) |
| /var/msgs | (reserved names, do not use) |
| /var/preserve | (reserved names, do not use) |
| /var/account | Process accounting logs (optional) |
| /var/crash | System crash dumps (optional) |
| /var/games | Variable game data (optional) |
| /var/mail | User mailbox files (optional) |
| /var/yp | Network Information Service (NIS) database files(optional) |

- (Mostly) Linux

| Directory | Description |
|-----------------|---|
| /proc | Kernel and process information virtual filesystem |
| /sys | Kernel and system information virtual filesystem |
| /usr/include | Header files included by C programs |
| /usr/src | Source code |
| /var/spool/cron | cron and at jobs |

- the `/dev/` directory
 - `/etc/fstab`: configuration of filesystems
 - `/etc/mtab` → `/proc/mounts`: mounted filesystems
 - `/proc/swaps`: swap filesystems
 - `df`: checking disk space and filesystems
 - Device Major and Minor Numbers
 - UUID - Universally Unique Identifier (128 bits)
 - GUID - Globally Unique Identifiers: `ls -al /dev/disk/by-uuid`
 - practically is NOT guaranteed unique
 - FUSE: Filesystem in Userspace
 - BBFS: Big Brother File System
- More Storage Structure
 - `tmpfs`
 - `objfs`
 - `ctfs`
 - `lofs`
 - `procfs`
 - `ufs`
 - `zfs`

A Typical Ubuntu 20.04 Work Station

```
rms46@pamulang1:~$ df
```

| Filesystem | 1K-blocks | Used | Available | Use% | Mounted on |
|-------------|------------------|------------|-----------|---------|-----------------------------------|
| udev | 8138664 | 0 | 8138664 | 0% | /dev |
| tmpfs | 1634140 | 1948 | 1632192 | 1% | /run |
| tmpfs | 8170684 | 210348 | 7960336 | 3% | /dev/shm |
| tmpfs | 5120 | 4 | 5116 | 1% | /run/lock |
| tmpfs | 8170684 | 0 | 8170684 | 0% | /sys/fs/cgroup |
| tmpfs | 1634136 | 76 | 1634060 | 1% | /run/user/1000 |
| /dev/sda1 | 98304 | 33523 | 64781 | 35% | /boot/efi |
| /dev/sda3 | 286082372 | 78565916 | 207516456 | 28% | /altfs/ntfs |
| /dev/sda5 | 32999120 | 9181772 | 22111364 | 30% | /altfs/linux1 |
| /dev/sda6 | 38186548 | 12054612 | 24162428 | 34% | /altfs/linux2 |
| /dev/sda7 | 126265680 | 13342928 | 106465768 | 12% | / |
| /dev/sdb2 | 62216964 | 13238156 | 45788588 | 23% | /var |
| /dev/sdb3 | 3532259904 | 2605226568 | 747535200 | 78% | /home |
| /dev/loop0 | 101632 | 101632 | 0 | 100% | /snap/core/10859 |
| /dev/loop1 | 65920 | 65920 | 0 | 100% | /snap/gtk-common-themes/1513 |
| /dev/loop2 | 66432 | 66432 | 0 | 100% | /snap/gtk-common-themes/1514 |
| /dev/loop3 | 678016 | 678016 | 0 | 100% | /snap/intellij-idea-community/273 |
| /dev/loop4 | 679040 | 679040 | 0 | 100% | /snap/intellij-idea-community/270 |
| /dev/loop5 | 52352 | 52352 | 0 | 100% | /snap/snap-store/498 |
| /dev/loop6 | 223232 | 223232 | 0 | 100% | /snap/gnome-3-34-1804/60 |
| /dev/loop7 | 267008 | 267008 | 0 | 100% | /snap/kde-frameworks-5-core18/32 |
| /dev/loop8 | 166784 | 166784 | 0 | 100% | /snap/gnome-3-28-1804/145 |
| /dev/loop9 | 102784 | 102784 | 0 | 100% | /snap/kotlin/57 |
| /dev/loop10 | 52352 | 52352 | 0 | 100% | /snap/snap-store/518 |
| /dev/loop11 | 56832 | 56832 | 0 | 100% | /snap/core18/1988 |
| /dev/loop12 | 33152 | 33152 | 0 | 100% | /snap/snapd/11107 |
| /dev/loop13 | 100736 | 100736 | 0 | 100% | /snap/core/10823 |
| ##### | #### TL;DR ##### | | | # ##### | |
| /dev/loop18 | 56832 | 56832 | 0 | 100% | /snap/core18/1944 |
| /dev/loop19 | 142080 | 142080 | 0 | 100% | /snap/chromium/1506 |

File Systems Implementation

- File System Layers / Structure
 - Application Programs
 - Logical File Systems
 - File-Organization Module
 - Basic File Systems
 - I/O Control
 - Hardware Device
- File System Implementation
- File Control Block
- FS In Memory Structure
- VFS: Virtual File Systems
 - How to support multiple File Systems
 - I.e. How to support multiple `open()/close()` `read()/write()` operations

Implementation and Allocation Method

- Directory Implementation
 - Linear List
 - Hash Table
- Allocation Method
 - Contiguous
 - Linked
 - Indexed
 - Combined Scheme
- Free Space Management
- Performance & Efficiency
- Unified Buffer Cache
- Recovery
- Log Structured File System

- File Systems
- File-System Mounting
- Partitions and Mounting
- File Sharing
- Virtual File Systems
- Remote File Systems
- Consistency Semantics
- NFS

Week 03: Check List (Deadline: 26 Sep 2021).

- ☐ Week 03 Token: **OS212W03**
- ☐ This page is <https://os.vlsm.org/Slides/check03.pdf>.
- ☐ More details: <https://osp4diss.vlsm.org/W03.html>.
- ☐ Assignment Check List:
 - ① Read OSC-10 (chapter 13 + chapter 14 + chapter 15)
 - ② Try Demos Week 02 and Week 03.
 - ③ Check if your ".bash_aliases" file is up-to-date. (See [OSP4DISS](#)).
 - ④ Visit <https://os.vlsm.org/GitHubPages/>. Review **Last Week TOP 10 List** and pick at least 3 out of your 10 next neighbors.
 - ⑤ Create your **TOP 10 List** of Week 03 (See <https://cbkadal.github.io/os212/W03/>). Do not use lecture material. Please be more creative!
 - ⑥ Update your log (e.g. <https://cbkadal.github.io/os212/TXT/mylog.txt>).
 - ⑦ Download <https://os.vlsm.org/WEEK/W03.tar.bz2.asc>. The passphrase will follow. The result ("W03-FUSE.txt") should be placed into a "W03/" folder and tarballed as "myW03.tar.bz2.asc"
 - ⑧ Update bash script (e.g. <https://cbkadal.github.io/os212/TXT/myscript.sh>).
 - ⑨ Make [SHA256SUM](#) and sign it (detached, armor) as [SHA256SUM.asc](#).

The End

- ☐ This is the end of the presentation.
- ☒ This is the end of the presentation.
 - This is the end of the presentation.