

# CSGE602055 Operating Systems

## CSF2600505 Sistem Operasi

### Week 09: File System & Persistent Storage

Rahmat M. Samik-Ibrahim

University of Indonesia

<http://rms46.vlsm.org/2/207.html>

Always check for the latest revision!

REV122 1-Mar-2018

# Operating Systems 2018-1 (Room 3114 Tue/Thu)

Class: A (10:00-12:00) | B (13:00-15:00) | C (16:00-18:00)

Week	Schedule	Topic	OSC9
Week 00	06 Feb - 12 Feb 2018	Intro & Review1	Ch. 1, 16
Week 01	13 Feb - 19 Feb 2018	Review2 & Scripting	Ch. 1, 2
Week 02	20 Feb - 26 Feb 2018	Protection, Security, Privacy, & C-language	Ch. 14, 15
Week 03	27 Feb - 05 Mar 2018	I/O, BIOS, Loader, & Systemd	Ch. 13
Week 04	06 Mar - 12 Mar 2018	Addressing, Shared Lib, & Pointer	Ch. 8
Week 05	13 Mar - 19 Mar 2018	Virtual Memory	Ch. 9
Reserved	20 Mar - 24 Mar 2018		
Mid-Term	03 Apr 2018	13:00 - 15:30 (UTS)	
Week 06	05 Apr - 11 Apr 2018	Concurrency: Processes & Threads	Ch. 3, 4
Week 07	12 Apr - 18 Apr 2018	Synchronization	Ch. 5, 7
Week 08	19 Apr - 25 Apr 2018	Scheduling	Ch. 6
Week 09	26 Apr - 05 May 2018	File System & Persistent Storage	Ch. 10, 11, 12
Week 10	14 May - 19 May 2018	I/O Programming & Network Sockets Programming	
Reserved	22 May - 22 May 2018		
Final	23 May - 26 May 2018	(UAS)	
Deadline	07 Jun 2018 16:00	Extra assignment <b>deadline</b>	

## • Operating Systems Check List

- ☐ Trace this document from <http://rms46.vlsm.org/2/207.html>
- ☐ Have a decent OS Book and map it to **OSC9**.
- ☐ Create **public** project "os181" on your github.com account.
  - ☐ Write in "README.md" file:
    - Special for Week 00: "**ZCZC Sistem Operasi 2018 Awal (1)**".
    - Add line on Week01: "**ZCZC W01 ...**".
    - On Week02: "**ZCZC W02 ...**".
    - On WeekXX: "**ZCZC WXX ...**".
- ☐ Encode your **QRC** with image size of approximately 250x250 pixels:  
"**OS181 CLASS ID GITHUB-ACCOUNT SSO-ACCOUNT SIAK-Full-Name**"  
Special for Week 00: Mail your **embedded** QRC to: os181@vlsm.org  
with Subject: [W00] CLASS ID SIAK-NAME.
- ☐ Write your Memo (with QRC) **every week**.
- ☐ Using your **SSO** account, login to badak.cs.ui.ac.id via kawung.cs.ui.ac.id.
  - ☐ Check folder badak:///extra/Week00/
  - ☐ Week00: Copy the folder to your home directory:  

```
cp -r /extra/Week00/W00-demos/ W00-demos/
```
  - ☐ For WeekXX: Copy the folder to your home directory:  

```
cp -r /extra/WeekXX/WXX-demos/ WXX-demos/ (XX=01, 02,... 10).
```
- ☐ **How to improve this document?**

# Agenda

- 1 Start
- 2 Agenda
- 3 Week 09
- 4 File Systems
- 5 Mass Storage Systems
- 6 RAID
- 7 Devices
- 8 FUSE
- 9 The End

# Week 09: File System & Persistent Storage

- Reference: (OSC9-ch10 OSC9-ch11 OSC9-ch12 demo-w09)
- File System Interface
- File Attribute
- File Operation
- Disk Structure and Organization
- File System Types
- Directory
- FS Mounting vs. Volume Based System
- FS Structure and Implementation
- File Control Block
- FS In Memory Structure
- VFS
- Directory Implementation

- File System Layers
  - Application Programs
  - Logical File Systems
  - File-Organization Module
  - Basic File Systems
  - I/O Control
  - Hardware Device
- Allocation Method
  - Contiguous
  - Linked
  - Indexed
  - Combined Scheme
- Cache
- STREAMS

- Mass Storage Structure
  - Solid State Disk
  - Storage Array
  - SAN
  - NAS
  - Scheduling: FCFS, SSTF, SCAN, C-SCAN, C-LOOK.
  - Disk Management
- Linux I/O Scheduling Algorithm.
  - Deadline Scheduler
  - Completely Fair Queueing (CFQ)

- RAID 0, 1, 5, 6, 10, 100
- Note (<http://www.commodore.ca/windows/raid5/raid5.htm>):
  - RAID was created to enhance data performance, reliability and availability.
  - Striping, parity checking and mirroring are three primary functions of RAID systems.
  - RAID performs its functions transparent to the operating system.
  - Systems are typically defined by ranks consisting of five disks each connected to one or two Disk Array Controllers.
  - Different RAID levels provide varying degrees of speed and data protection.



- 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

# FUSE

```
>>>>> $ ls -al
total 16
drwxr-xr-x  3 demo demo 4096 May  2  2017 .
drwxr-xr-x 13 demo demo 4096 Sep 22 15:03 ..
drwxr-xr-x  5 demo demo 4096 Aug 27 15:28 fuse-tutorial-2016-03-25
-rw-r--r--  1 demo demo  192 May  2  2017 readme.txt
```

```
>>>>> $ cat readme.txt
REV01 Tue May  2 10:21:45 WIB 2017
START Mon Nov 21 14:39:48 WIB 2016
=====
```

1. `cd fuse-tutorial-2016-03-25`
2. `lynx index.html`
3. `make`
4. `cat example/ZREADME.txt`

# FUSE (2)

```
>>>> $ lynx index.html
>>>> $ lynx -dump index.html > tmpmp.txt
>>>> $ vi tmpmp.txt
>>>> $
```

## Writing a FUSE Filesystem: a Tutorial

Joseph J. Pfeiffer, Jr., Ph.D.  
Emeritus Professor  
Department of Computer Science  
New Mexico State University  
[1]pfeiffer@cs.nmsu.edu

Version of 2016-03-25

One of the real contributions of Unix has been the view that "everything is a file". A tremendous number of radically different sorts of objects, from data storage to file format conversions to internal operating system data structures, have been mapped to the file abstraction.

One of the more recent directions this view has taken has been Filesystems in User Space, or FUSE (no, the acronym really doesn't work. Oh well). The idea here is that if you can envision your interaction with an object in terms of a directory structure and filesystem operations, you can write a FUSE file system to provide that interaction. You just write code that implements file operations like `open()`, `read()`, and `write()`; when your filesystem is mounted, programs are able to access the data using the standard file operation system calls, which call your code.

[.....]

# FUSE (3)

```
>>>> $ make clean
Making clean in example
make[1]: Entering directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25/example'
rm -rf mountdir rootdir
rm -rf bbfs.log
make[1]: Leaving directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25/example'
Making clean in html
make[1]: Entering directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25/html'
make[1]: Nothing to be done for 'clean'.
make[1]: Leaving directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25/html'
Making clean in src
make[1]: Entering directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25/src'
test -z "bbfs" || rm -f bbfs
rm -f *.o
make[1]: Leaving directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25/src'
make[1]: Entering directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25'
make[1]: Nothing to be done for 'clean-am'.
make[1]: Leaving directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25'
```

# FUSE (4)

```
>>>> $ make
Making all in example
make[1]: Entering directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25/example'
mkdir -p mountdir
mkdir -p rootdir
echo "bogus file" > rootdir/bogus.txt
make[1]: Leaving directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25/example'
Making all in html
make[1]: Entering directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25/html'
make[1]: Nothing to be done for 'all'.
make[1]: Leaving directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25/html'
Making all in src
make[1]: Entering directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25/src'
make all-am
make[2]: Entering directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25/src'
gcc -DHAVE_CONFIG_H -I. -D_FILE_OFFSET_BITS=64 -I/usr/include/fuse -g -O2 -MT bbfs.o -MD -MP -MF
.deps/bbfs.Tpo -c -o bbfs.o bbfs.c
mv -f .deps/bbfs.Tpo .deps/bbfs.Po
gcc -DHAVE_CONFIG_H -I. -D_FILE_OFFSET_BITS=64 -I/usr/include/fuse -g -O2 -MT log.o -MD -MP -MF
.deps/log.Tpo -c -o log.o log.c
mv -f .deps/log.Tpo .deps/log.Po
gcc -D_FILE_OFFSET_BITS=64 -I/usr/include/fuse -g -O2 -o bbfs bbfs.o log.o -lfuse -pthread
make[2]: Leaving directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25/src'
make[1]: Leaving directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25/src'
make[1]: Entering directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25'
make[1]: Nothing to be done for 'all-am'.
make[1]: Leaving directory '/home/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25'
>>>> $
```

# FUSE (5)

```
>>>> $ cd example/
```

```
>>>> $ ls -al
```

```
total 24
drwxr-xr-x 4 demo demo 4096 Nov 14 11:08 .
drwxr-xr-x 5 demo demo 4096 Nov 14 09:52 ..
-rw-r--r-- 1 demo demo  207 Nov 14 09:59 Makefile
drwxr-xr-x 2 demo demo 4096 Nov 14 11:08 mountdir
drwxr-xr-x 2 demo demo 4096 Nov 14 11:08 rootdir
-rw-r--r-- 1 demo demo  576 Nov 14 11:06 ZREADME.txt
```

```
>>>> $ cat ZREADME.txt
```

```
REV01 Tue Nov 14 11:05:17 WIB 2017
```

```
START Mon Nov 21 14:41:33 WIB 2016
```

```
=====
```

```
TO TRY:
```

```
$ ls -al rootdir
```

```
$ ls -al mountdir
```

```
$ ../src/bbfs rootdir/ mountdir/
```

```
$ df
```

```
$ ls -al rootdir
```

```
$ ls -al mountdir
```

```
TO PLAY:
```

```
$ cd mountdir
```

```
$ touch blah-blah-blah.txt
```

```
$ ls -al
```

```
$ cd ..
```

```
$ ls -al rootdir
```

```
[.....]
```

# FUSE (6)

```
>>>> $ ls -al rootdir/
total 12
drwxr-xr-x 2 demo demo 4096 Nov 14 11:08 .
drwxr-xr-x 4 demo demo 4096 Nov 14 11:08 ..
-rw-r--r-- 1 demo demo   11 Nov 14 11:08 bogus.txt
```

```
>>>> $ ls -al mountdir/
total 8
drwxr-xr-x 2 demo demo 4096 Nov 14 11:08 .
drwxr-xr-x 4 demo demo 4096 Nov 14 11:08 ..
```

```
>>>> $ df
Filesystem      1K-blocks      Used Available Use% Mounted on
udev             10240          0       10240   0% /dev
tmpfs            1639432      29352     1610080   2% /run
/dev/vda2        9515660     1061184     7948060  12% /
/dev/vdc1        32895760    12041032     19160676  39% /usr
tmpfs            4098580          0     4098580   0% /dev/shm
tmpfs            5120          0         5120   0% /run/lock
tmpfs            4098580          0     4098580   0% /sys/fs/cgroup
/dev/vdb1        515929528    20127528    469571268   5% /home
tmpfs            819716          0      819716   0% /run/user/1002
tmpfs            819716          0      819716   0% /run/user/5428
```

```
>>>> $ ../src/bbfs rootdir/ mountdir/
Fuse library version 2.9
about to call fuse_main
```

# FUSE (7)

```
>>>> $ df
Filesystem      1K-blocks      Used Available Use% Mounted on
udev              10240          0        10240   0% /dev
tmpfs            1639432      29352     1610080   2% /run
/dev/vda2        9515660    1061184     7948060  12% /
/dev/vdc1       32895760   12041032     19160676  39% /usr
tmpfs            4098580          0     4098580   0% /dev/shm
tmpfs             5120          0         5120   0% /run/lock
tmpfs            4098580          0     4098580   0% /sys/fs/cgroup
/dev/vdb1       515929528  20127532   469571264   5% /home
tmpfs            819716          0      819716   0% /run/user/1002
tmpfs            819716          0      819716   0% /run/user/5428
bbfs            515929528  20127532   469571264   5%
/home/demo/git/demo/demos/week09-File-Storage-System/fuse-tutorial-2016-03-25/example/mountdir

>>>> $ ls -al mountdir/
total 12
drwxr-xr-x 2 demo demo 4096 Nov 14 11:08 .
drwxr-xr-x 4 demo demo 4096 Nov 14 11:13 ..
-rw-r--r-- 1 demo demo  11 Nov 14 11:08 bogus.txt

>>>> $ ls -al rootdir/
total 12
drwxr-xr-x 2 demo demo 4096 Nov 14 11:08 .
drwxr-xr-x 4 demo demo 4096 Nov 14 11:13 ..
-rw-r--r-- 1 demo demo  11 Nov 14 11:08 bogus.txt

>>>> $
```



# FUSE (8)

```
>>>> $ touch mountdir/adding-something-to-mountdir.txt
```

```
>>>> $ ls -al mountdir/
```

```
total 12
drwxr-xr-x 2 demo demo 4096 Nov 14 11:19 .
drwxr-xr-x 4 demo demo 4096 Nov 14 11:13 ..
-rw-r--r-- 1 demo demo   0 Nov 14 11:19 adding-something-to-mountdir.txt
-rw-r--r-- 1 demo demo  11 Nov 14 11:08 bogus.txt
```

```
>>>> $ ls -al rootdir/
```

```
total 12
drwxr-xr-x 2 demo demo 4096 Nov 14 11:19 .
drwxr-xr-x 4 demo demo 4096 Nov 14 11:13 ..
-rw-r--r-- 1 demo demo   0 Nov 14 11:19 adding-something-to-mountdir.txt
-rw-r--r-- 1 demo demo  11 Nov 14 11:08 bogus.txt
```

```
>>>> $ fusermount -u mountdir
```

```
>>>> $ ls -al mountdir/
```

```
total 8
drwxr-xr-x 2 demo demo 4096 Nov 14 11:08 .
drwxr-xr-x 4 demo demo 4096 Nov 14 11:13 ..
```

```
>>>> $ ls -al rootdir/
```

```
total 12
drwxr-xr-x 2 demo demo 4096 Nov 14 11:19 .
drwxr-xr-x 4 demo demo 4096 Nov 14 11:13 ..
-rw-r--r-- 1 demo demo   0 Nov 14 11:19 adding-something-to-mountdir.txt
-rw-r--r-- 1 demo demo  11 Nov 14 11:08 bogus.txt
```

```
>>>> $
```

# The End

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