

CSGE602055 Operating Systems

CSF2600505 Sistem Operasi

Week 05: Virtual Memory

Rahmat M. Samik-Ibrahim

University of Indonesia

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

Always check for the latest revision!

REV132 11-Apr-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	Overview 1	Ch. 1, 16
Week 01	13 Feb - 19 Feb 2018	Overview 2 & 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 - 07 May 2018	File System & Persistent Storage	Ch. 10, 11, 12
Reserved	08 May - 14 May 2018		
Week 10	15 May - 21 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 deadline	

• The Check List (Operating Systems)

- ☐ **Starting Point:** <http://rms46.vlsm.org/2/207.html>
- ☐ **Text Book:** any recent/decent OS book but map it to **OSC9**.
- ☐ Create **public** project "os181" on your github.com account.
 - ☐ Create file "README.md" and add an extra line every week. For e.g.¹:
ZCZC Sistem Operasi 2018 Awal (1)
ZCZC W01 Have tried demo for week 01.
ZCZC W02 Week 02 is done.
ZCZC W03 Week 03 is done.
- ☐ 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/
 - ☐ Every week, copy the weekly demo files to your own home directory.
Eg. for Week00:
cp -r /extra/Week00/W00-demos/ W00-demos/

¹Week 00 line is optional. The following "ZCZC WXX" weekly tags are mandatory.

Week 05: Memory

- 1 Start
- 2 Week 05
- 3 Virtual Memory
- 4 Memory Allocation Algorithm
- 5 TOP
- 6 06-memory
- 7 The End

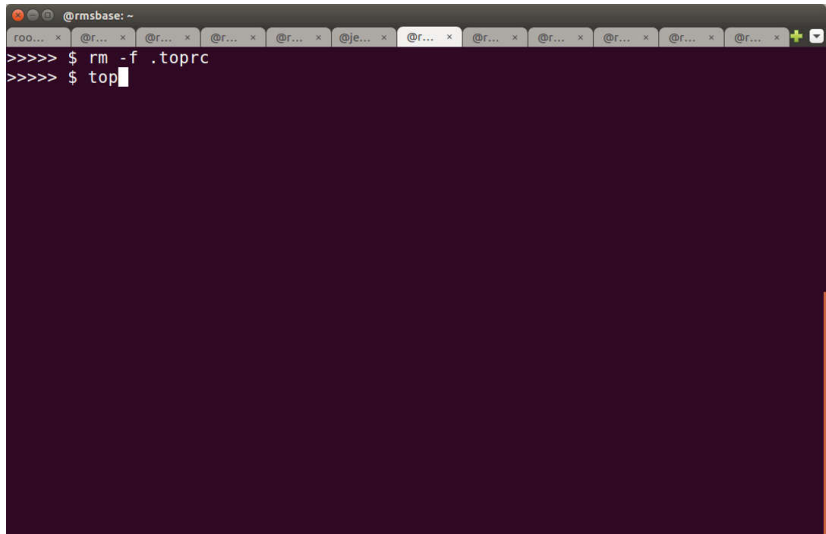
Virtual Memory

- Reference: (OSC9-ch09 demo-w05)
- Virtual Memory: Separation Logical from Physical.
- Virtual Address Space: logical view.
- Demand Paging
- Page Flags: Valid / Invalid
- Page Fault
- Demand Paging Performance
- Copy On Write (COW)
- Page Replacement Algorithm
 - Reference String
 - First-In-First-Out (FIFO)
 - Belady Anomaly
 - Optimal Algorithm
 - Least Recently Used (LRU)
 - LRU Implementation
 - Least Frequently Used (LFU)
 - Most Frequently Used (MFU)

Allocation Algorithm

- Page-Buffering Algorithms
- Allocation of Frames
- Fixed Allocation
- Priority Allocation
- Global vs. Local Allocation
- Non-Uniform Memory Access (NUMA)
- Thrashing
- Working-Set Model
- Shared Memory via Memory-Mapped I/O
- Kernel
 - Buddy System Allocator
 - Slab Allocator

TOP



A terminal window titled "@rmsbase: ~" with multiple tabs. The terminal shows the following commands and output:

```
>>>>> $ rm -f .toprc
>>>>> $ top
```

The terminal output is currently blank, indicating that the 'top' command has been executed but its output has not yet been displayed.

Figure: top

TOP (2)

```
@rmsbase: ~
top - 18:37:28 up 14:07, 1 user, load average: 2.77, 2.71, 2.74
Tasks: 128 total, 1 running, 127 sleeping, 0 stopped, 0 zombie
%Cpu(s): 14.6 us, 17.2 sy, 0.0 ni, 68.1 id, 0.0 wa, 0.0 hi, 0.0 si, 0.0 st
KiB Mem: 8197060 total, 935152 used, 7261908 free, 191512 buffers
KiB Swap: 683004 total, 0 used, 683004 free. 639140 cached Mem
```

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
518	root	20	0	162032	112	0	S	225.2	0.0	1882:33	rngd
3448	root	20	0	0	0	0	S	14.0	0.0	0:09.14	kworker/0:2
3198	root	20	0	0	0	0	S	9.6	0.0	5:29.03	kworker/4:0
3062	root	20	0	0	0	0	S	5.0	0.0	11:55.39	kworker/1:2
3289	root	20	0	0	0	0	S	2.3	0.0	3:41.00	kworker/6:1
7	root	20	0	0	0	0	S	2.0	0.0	1:08.44	rcu_sched
3376	root	20	0	0	0	0	S	1.3	0.0	0:18.73	kworker/5:0
1914	root	20	0	0	0	0	S	0.3	0.0	13:10.69	kworker/2:1
1	root	20	0	28684	4736	3012	S	0.0	0.1	0:02.91	systemd
2	root	20	0	0	0	0	S	0.0	0.0	0:00.01	kthreadd
3	root	20	0	0	0	0	S	0.0	0.0	0:15.26	ksoftirqd/0
5	root	0	-20	0	0	0	S	0.0	0.0	0:00.00	kworker/0:+
8	root	20	0	0	0	0	S	0.0	0.0	0:00.00	rcu_bh
9	root	rt	0	0	0	0	S	0.0	0.0	0:00.00	migration/0
10	root	rt	0	0	0	0	S	0.0	0.0	0:00.25	watchdog/0
11	root	rt	0	0	0	0	S	0.0	0.0	0:00.28	watchdog/1
12	root	rt	0	0	0	0	S	0.0	0.0	0:00.00	migration/1
13	root	20	0	0	0	0	S	0.0	0.0	0:06.80	ksoftirqd/1

Figure: "h" = help

TOP (3)

```
@rmsbase: ~
roo... x @f... x @f... x @f... x @f... x @je... x @f... x @f... x @f... x @f... x @f... x @f... x +
Fields Management for window 1:Def, whose current sort field is %CPU
Navigate with Up/Dn, Right selects for move then <Enter> or Left commits,
'd' or <Space> toggles display, 's' sets sort. Use 'q' or <Esc> to end!

* PID = Process Id      TTY = Controlling T      USED = Res+Swap Size
USER = Effective Use    TPGID = Tty Process G    nsIPC = IPC namespace
PR = Priority           SID = Session Id        nsMNT = MNT namespace
NI = Nice Value        nTH = Number of Thr     nsNET = NET namespace
VIRT = Virtual Image    P = Last Used Cpu       nsPID = PID namespace
RES = Resident Size     TIME = CPU Time         nsUSER = USER namespace
SHR = Shared Memory     SWAP = Swapped Size     nsUTS = UTS namespace
S = Process Statu      CODE = Code Size (Ki
%CPU = CPU Usage        DATA = Data+Stack (K
%MEM = Memory Usage     nMaj = Major Page Fa
TIME+ = CPU Time, hun   nMin = Minor Page Fa
COMMAND = Command Name/ nDRT = Dirty Pages C
PPID = Parent Proces    WCHAN = Sleeping in F
UID = Effective Use     Flags = Task Flags <s
RUID = Real User Id     CGROUPS = Control Group
RUSER = Real User Nam   SUPGIDS = Supp Groups I
SUID = Saved User Id    SUPGRPS = Supp Groups N
SUSER = Saved User Na   TGID = Thread Group
GID = Group Id          ENVIRON = Environment v
GROUP = Group Name      vMj = Major Faults
PRGP = Process Group    vMn = Minor Faults
```

Figure: Moving Fields: "f"

TOP (4)

```
@rmsbase: ~
roo... x @f... x @f... x @f... x @f... x @je... x @f... x @f... x @f... x @f... x @f... x @f... x +
Fields Management for window 1:Def, whose current sort field is %CPU
Navigate with Up/Dn, Right selects for move then <Enter> or Left commits,
'd' or <Space> toggles display, 's' sets sort. Use 'q' or <Esc> to end!

* PID      = Process Id      SUID       = Saved User Id    vMn        = Minor Faults
* VIRT     = Virtual Image  SUSER      = Saved User Na    nsIPC      = IPC namespace
* RES      = Resident Size  GID        = Group Id        nsMNT      = MNT namespace
* SHR      = Shared Memory  GROUP      = Group Name     nsNET      = NET namespace
* SWAP     = Swapped Size   PGRP       = Process Group nsPID      = PID namespace
* CODE     = Code Size (Ki  TTY         = Controlling T nsUSER     = USER namespac
* DATA    = Data+Stack (K  TPGID      = Tty Process G nsUTS      = UTS namespace
* USED     = Res+Swap Size  SID         = Session Id
* nDRT     = Dirty Pages C  nTH        = Number of Thr
* PPID     = Parent Proces  P           = Last Used Cpu
%MEM       = Memory Usage  TIME       = CPU Time
USER       = Effective Use  nMaj       = Major Page Fa
PR         = Priority      nMin       = Minor Page Fa
NI         = Nice Value    WCHAN      = Sleeping in F
S          = Process Statu Flags        = Task Flags <s
%CPU       = CPU Usage     CGROUPS    = Control Group
TIME+      = CPU Time, hun SUPGIDS     = Supp Groups I
COMMAND    = Command Name/ SUPGRPS     = Supp Groups N
UID        = Effective Use TGID        = Thread Group
RUID       = Real User Id  ENVIRON    = Environment v
RUSER      = Real User Nam vMj         = Major Faults
```

Figure: Moving Fields

TOP (5)

```
@rmsbase: ~/Downloads
top - 19:57:14 up 11:38, 1 user, load average: 0.43, 0.54, 0.58
Tasks: 285 total, 2 running, 283 sleeping, 0 stopped, 0 zombie
%Cpu(s): 3.8 us, 1.3 sy, 0.0 ni, 94.6 id, 0.3 wa, 0.0 hi, 0.0 si, 0.0 st
KiB Mem : 16385976 total, 269672 free, 3179788 used, 12936516 buff/cache
KiB Swap: 1000444 total, 994752 free, 5692 used. 12649780 avail Mem
```

PID	VIRT	RES	SHR	SWAP	CODE	DATA	USED	nDRT
3547	2377296	394828	165776	0	196	1642748	394828	0
1234	278216	87880	59116	0	2288	25164	87880	0
3321	2683572	433176	149376	0	196	1856708	433176	0
2708	1687448	214112	80608	0	12	1179008	214112	0
2841	679488	50860	30484	0	292	389096	50860	0
3748	1896812	321288	76656	0	133688	1474084	321288	0
3971	2047252	440112	97384	0	133688	1587052	440112	0
32501	630768	33500	27960	0	76	373220	33500	0
4067	8554396	320516	109756	0	196	7954584	320516	0
4130	2391592	341632	117636	0	196	1717824	341632	0
22635	2198448	274812	108000	0	196	1532152	274812	0
1292	0	0	0	0	0	0	0	0
2514	930224	34304	26028	0	36	448864	34304	0
3233	4515228	360812	126784	0	133688	3757984	360812	0
32495	33488	3380	2836	0	96	1264	3380	0
2388	44036	4424	2724	0	212	1716	4424	0
2412	423204	11380	5264	0	152	374232	11380	0
2512	685824	74188	36868	0	552	399836	74188	0

Figure: Write Configuration .toprc: "W"

06-memory

```
/* Copyright (C) 2016-2018 Rahmat M. Samik-Ibrahim
 * http://rahmatm.samik-ibrahim.vlsm.org/
 * This program is free script/software. This program is distributed in the
 * hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
 * implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
 * REV04 Mon Mar 12 17:33:30 WIB 2018
 * START Mon Oct 3 09:26:51 WIB 2016
 */
#define MSIZE0 0x10000
#define MSIZE1 0x10008
#define MSIZE2 0x10009
#define MSIZE3 0x1000A
#define MSIZE4 0x20978
#define MSIZE5 0x20979
#define MSIZE6 0x2097A
#define MSIZE7 0xF0000
#define MSIZE8 0x10000
#define MSIZE9 0x1000
#define LINE 75
#define MAXSTR 80
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <string.h>
#include <sys/types.h>

void printLine(int line) {
    while(line-- > 0) putchar('x');
    putchar('\n');
    fflush(NULL);
}
```

06-memory (2)

```
void main (void) {
    int  msize[] = {MSIZE0, MSIZE1, MSIZE2, MSIZE3, MSIZE4,
                    MSIZE5, MSIZE6, MSIZE7, MSIZE8, MSIZE9};

    int  ii, jj;
    int  myPID   = (int) getpid();
    char strSYS1[MAXSTR], strOUT[MAXSTR];
    char* chrStr  = strSYS1;
    char* chrPTR;

    printLine(LINE);
    sprintf(strSYS1, "top -b -n 1 -p%d | tail -5", myPID);
    system (strSYS1);
    sprintf(strSYS1, "top -b -n 1 -p%d | tail -1", myPID);
    for (ii=0; ii< (sizeof(msize)/sizeof(int)); ii++){
        chrStr = malloc(msize[ii]);
        fgets(strOUT, sizeof(strOUT)-1, popen(strSYS1, "r"));
        strOUT[(int) strlen(strOUT)-1]='\0';
        printf("%s [%X]\n", strOUT, msize[ii]);
        free(chrStr);
    }
    for (ii=0; ii< (sizeof(msize)/sizeof(int)); ii++){
        chrPTR = chrStr = malloc(msize[ii]);
        for (jj=0;jj<msize[ii];jj++)
            *chrPTR++='x';
        fgets(strOUT, sizeof(strOUT)-1, popen(strSYS1, "r"));
        strOUT[(int) strlen(strOUT)-1]='\0';
        printf("%s [%X]\n", strOUT, msize[ii]);
        free(chrStr);
    }
}
```

06-memory (2)

```
>>>>> $ ./06-memory
```

[illegible]

```
KiB Mem:  8197060 total,  957928 used,  7239132 free,  192520 buffers
```

```
KiB Swap: 683004 total, 0 used, 683004 free. 660108 cached
```

Mem

PID	VIRT	RES	SHR	SWAP	CODE	DATA	USED	nDRT
4362	4172	640	564	0	4	320	640	0
4362	4172	640	564	0	4	320	640	0 [10000]
4362	4172	640	564	0	4	320	640	0 [10008]
4362	4308	640	564	0	4	456	640	0 [10009]
4362	4244	1176	1068	0	4	392	1176	0 [1000A]
4362	4244	1176	1068	0	4	392	1176	0 [20978]
4362	4376	1176	1068	0	4	524	1176	0 [20979]
4362	4376	1192	1068	0	4	524	1192	0 [2097A]
4362	5340	1192	1068	0	4	1488	1192	0 [F0000]
4362	4376	1200	1068	0	4	524	1200	0 [10000]
4362	4376	1200	1068	0	4	524	1200	0 [1000]

06-memory (3)

4362	4376	1200	1068	0	4	524	1200	0 [1000]
4362	4376	1200	1068	0	4	524	1200	0 [10000]
4362	4376	1276	1068	0	4	524	1276	0 [10008]
4362	4376	1276	1068	0	4	524	1276	0 [10009]
4362	4376	1284	1068	0	4	524	1284	0 [1000A]
4362	4376	1284	1068	0	4	524	1284	0 [20978]
4362	4376	1352	1068	0	4	524	1352	0 [20979]
4362	4376	1352	1068	0	4	524	1352	0 [2097A]
4362	5340	2144	1068	0	4	1488	2144	0 [F0000]
4362	5340	2324	1068	0	4	1488	2324	0 [10000]
4362	5340	2324	1068	0	4	1488	2324	0 [1000]

>>>>> \$

The End

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