

## Assignment – 1 : Operating Systems Laboratory

1. The following are known using procsfs:

- My machine has 8 cores. (cat /proc/cpuinfo)
- Total memory is 3184424 kB of which 2927296 kB is free. (cat /proc/meminfo)
- 228164 context switches happened since system booted. (cat /proc/stat) ctxt line in the above command gives the number
- 830 processes have been forked. (cat /proc/stat) processes line in the above command gives the number

2. The following are known using various commands shown:

- cpu : CPU is the bottleneck for this process. The output for the top command is as follows:

```
yashwin@YASHWIN-ENAMADI: ~
Tasks:  9 total,  2 running,  7 sleeping,  0 stopped,  0 zombie
%Cpu(s): 12.5 us,  0.0 sy,  0.0 ni, 87.4 id,  0.0 wa,  0.0 hi,  0.1 si,  0.0 st
MiB Mem : 3109.8 total, 3017.3 free,  66.7 used,  25.8 buff/cache
MiB Swap: 1024.0 total, 1024.0 free,  0.0 used, 2952.1 avail Mem

  PID USER      PR  NI   VIRT   RES   SHR  S  %CPU  %MEM     TIME+ COMMAND
  40 yashwin   20   0   2360    576    512 R 100.0   0.0   0:59.48 cpu
    1 root      20   0    892    548    484 S   0.0   0.0   0:00.03 init
    7 root      20   0    892     80     16 S   0.0   0.0   0:00.00 init
    8 root      20   0    892     80     16 S   0.0   0.0   0:00.01 init
    9 yashwin   20   0  10036   5112   3404 S   0.0   0.2   0:00.11 bash
   22 root      20   0    892     80     16 S   0.0   0.0   0:00.00 init
   23 root      20   0    892     80     16 S   0.0   0.0   0:00.00 init
   24 yashwin   20   0  10036   4948   3252 S   0.0   0.2   0:00.06 bash
   41 yashwin   20   0  10860   3704   3188 R   0.0   0.1   0:00.00 top

yashwin@YASHWIN-ENAMADI:~$ vmstat -S M 2 5
procs -----memory-----swap-----io-----system-- -----cpu-----
 r b  swpd   free   buff   cache    si   so    bi   bo    in  cs us sy id wa st
  1 0      0   2785    12   237      0    0      5  109  85 387  0  0 99  0  0
  1 0      0   2785    12   237      0    0      0    0   13  24 12  0 87  0  0
  1 0      0   2785    12   237      0    0      0    0   15  27 12  0 87  0  0
  1 0      0   2785    12   237      0    0      0    0   11  22 12  0 87  0  0
  1 0      0   2785    12   237      0    0      0    0   11  23 12  0 87  0  0

yashwin@YASHWIN-ENAMADI:~$ sar -u 2 5
Linux 4.19.104-microsoft-standard (YASHWIN-ENAMADI)      08/20/20      _x86_64_      (8 CPU)

00:33:08      CPU      %user      %nice      %system      %iowait      %steal      %idle
00:33:10      all      12.48      0.00      0.12      0.00      0.00      87.39
00:33:12      all      12.53      0.00      0.19      0.00      0.00      87.28
00:33:14      all      12.54      0.00      0.12      0.00      0.00      87.34
00:33:16      all      12.49      0.00      0.12      0.00      0.00      87.38
00:33:18      all      12.48      0.00      0.12      0.00      0.00      87.39
Average:      all      12.51      0.00      0.14      0.00      0.00      87.36
```

It is clearly evident that cpu(PID : 40) is using 100% of CPU.

As this program is highly computational in nature, without accessing any other resources such as I/O devices and disk, it is quite expected that the bottleneck for this process is CPU.

b. cpu-print :

```
yashwin@YASHWIN-ENAMADI:~$ top
top - 00:26:03 up 1:16, 0 users, load average: 0.08, 0.33, 0.32
Tasks: 9 total, 2 running, 7 sleeping, 0 stopped, 0 zombie
%Cpu(s): 0.8 us, 5.1 sy, 0.0 ni, 94.1 id, 0.0 wa, 0.0 hi, 0.0 si, 0.0 st
MiB Mem : 3109.8 total, 2785.3 free, 74.9 used, 249.7 buff/cache
MiB Swap: 1024.0 total, 1024.0 free, 0.0 used. 2890.6 avail Mem
```

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
548	yashwin	20	0	2492	712	644	R	32.3	0.0	0:03.29	cpu-print
8	root	20	0	892	76	16	S	2.7	0.0	0:02.72	init
1	root	20	0	892	544	484	S	0.0	0.0	0:00.04	init
7	root	20	0	892	76	16	S	0.0	0.0	0:00.00	init
9	yashwin	20	0	10036	5000	3272	S	0.0	0.2	0:02.51	bash
301	root	20	0	892	76	16	S	0.0	0.0	0:00.00	init
302	root	20	0	892	76	16	S	0.0	0.0	0:00.69	init
303	yashwin	20	0	10036	5100	3388	S	0.0	0.2	0:01.60	bash
549	yashwin	20	0	10860	3816	3260	R	0.0	0.1	0:00.00	top

```
yashwin@YASHWIN-ENAMADI:~$ vmstat -S M 2 5
procs -----memory----- --swap-- ----io---- -system-- -----cpu-----
r b swpd free buff cache si so bi bo in cs us sy id wa st
1 0 0 2785 12 237 0 0 5 118 76 366 0 0 99 0 0
0 0 0 2785 12 237 0 0 0 0 15227 49803 0 6 93 0 0
0 0 0 2785 12 237 0 0 0 0 13846 46698 0 6 93 0 0
0 0 0 2785 12 237 0 0 0 0 16003 53258 1 6 94 0 0
0 0 0 2785 12 237 0 0 0 0 15652 53069 0 7 92 0 0
```

```
yashwin@YASHWIN-ENAMADI:~$ sar -u 2 5
Linux 4.19.104-microsoft-standard (YASHWIN-ENAMADI) 08/20/20 _x86_64_ (8 CPU)

00:26:32      CPU      %user      %nice      %system      %iowait      %steal      %idle
00:26:34      all       0.50       0.00       6.30       0.00       0.00      93.20
00:26:36      all       0.62       0.00       7.29       0.00       0.00      92.09
00:26:38      all       0.44       0.00       6.30       0.00       0.00      93.26
00:26:40      all       0.31       0.00       6.46       0.00       0.00      93.22
00:26:42      all       0.38       0.00       5.32       0.00       0.00      94.30
Average:      all       0.45       0.00       6.34       0.00       0.00      93.21
```

In this case, it is very evident from the output of vmstat cmd that, high number of interrupts and context switches are occurred during the execution. So, the bottleneck for this process is I/O operations. In the cpu section, we also notice CPU is idle for most of the time. Hence, CPU is definitely not the bottleneck for this process. As the program prints output for every short duration of time, it is quite expected that either CPU or I/O operations must be the bottleneck for this process. But user time is very less for the process. So, it is clear that I/O operations become the bottleneck.

c. disk :

```
yashwin@YASHWIN-ENAMADI: ~
top - 00:06:56 up 57 min, 0 users, load average: 0.89, 0.46, 0.30
Tasks: 9 total, 2 running, 7 sleeping, 0 stopped, 0 zombie
%Cpu(s): 0.1 us, 2.5 sy, 0.0 ni, 97.4 id, 0.0 wa, 0.0 hi, 0.0 si, 0.0 st
MiB Mem : 3109.8 total, 2791.1 free, 73.9 used, 244.9 buff/cache
MiB Swap: 1024.0 total, 1024.0 free, 0.0 used. 2892.3 avail Mem

  PID USER      PR  NI  VIRT  RES  SHR S %CPU  %MEM    TIME+  COMMAND
  370 yashwin   20   0   2492   580   512 R  18.0   0.0   0:10.48  disk
  377 yashwin   20   0  10860  3764  3248 R   0.3   0.1   0:00.02  top
    1 root      20   0    892   544   484 S   0.0   0.0   0:00.04  init
    7 root      20   0    892    76    16 S   0.0   0.0   0:00.00  init
    8 root      20   0    892    76    16 S   0.0   0.0   0:02.20  init
    9 yashwin   20   0  10036  5000  3272 S   0.0   0.2   0:01.88  bash
  301 root      20   0    892    76    16 S   0.0   0.0   0:00.00  init
  302 root      20   0    892    76    16 S   0.0   0.0   0:00.05  init
  303 yashwin   20   0  10036  5100  3388 S   0.0   0.2   0:01.50  bash

yashwin@YASHWIN-ENAMADI: ~
yashwin@YASHWIN-ENAMADI:~$ vmstat -S M 2 5
procs -----memory----- --swap--  -----io----- -system--  -----cpu-----
 r b   swpd   free   buff   cache   si   so    bi   bo    in   cs us sy id wa st
  1 0     0   2786    12   237    0    0     4   84   68  311  0  0 99  0  0
  1 0     0   2786    12   237    0    0     0    0    13  21 13  0 87  0  0
  1 0     0   2786    12   237    0    0     0    0   10  20 13  0 88  0  0
  1 0     0   2786    12   237    0    0     0    0   10  19 13  0 88  0  0
  1 0     0   2786    12   237    0    0     0    0   11  20 12  0 87  0  0

yashwin@YASHWIN-ENAMADI:~$ sar -u 2 5
Linux 4.19.104-microsoft-standard (YASHWIN-ENAMADI)      08/20/20      _x86_64_      (8 CPU)

00:57:17      CPU      %user      %nice      %system      %iowait      %steal      %idle
00:57:19      all      12.48      0.00      0.12      0.00      0.00      87.39
00:57:21      all      12.51      0.00      0.00      0.00      0.00      87.49
00:57:23      all      12.50      0.00      0.00      0.00      0.00      87.50
00:57:25      all      12.48      0.00      0.06      0.00      0.00      87.45
00:57:27      all      12.50      0.00      0.00      0.00      0.00      87.50
Average:      all      12.50      0.00      0.04      0.00      0.00      87.47
```

In this process, the disk is the bottleneck. Since, the process accesses the disk for reading every file among 10k files, each of size 2MB, the disk becomes the bottleneck of the process.

d. disk1 :

```
yashwin@YASHWIN-ENAMADI:~$ top
top - 00:21:04 up 1:11, 0 users, load average: 0.35, 0.22, 0.26
Tasks: 9 total, 1 running, 8 sleeping, 0 stopped, 0 zombie
%Cpu(s): 0.2 us, 2.4 sy, 0.0 ni, 97.4 id, 0.0 wa, 0.0 hi, 0.0 si, 0.0 st
MiB Mem : 3109.8 total, 2785.3 free, 75.2 used, 249.3 buff/cache
MiB Swap: 1024.0 total, 1024.0 free, 0.0 used. 2890.3 avail Mem

  PID USER      PR  NI  VIRT  RES  SHR S %CPU  %MEM    TIME+  COMMAND
  538 yashwin   20   0   2492   520   456 D  18.7   0.0   0:04.36  disk1
    1 root      20   0    892   544   484 S   0.0   0.0   0:00.04  init
    7 root      20   0    892    76    16 S   0.0   0.0   0:00.00  init
    8 root      20   0    892    76    16 S   0.0   0.0   0:02.24  init
    9 yashwin   20   0  10036  5000  3272 S   0.0   0.2   0:02.50  bash
  301 root      20   0    892    76    16 S   0.0   0.0   0:00.00  init
  302 root      20   0    892    76    16 S   0.0   0.0   0:00.68  init
  303 yashwin   20   0  10036  5100  3388 S   0.0   0.2   0:01.57  bash
  543 yashwin   20   0  10860  3768  3216 R   0.0   0.1   0:00.01  top
```



```

yashwin@YASHWIN-ENAMADI:~$ vmstat -S M 2 5
procs -----memory-----swap-----io-----system-- -----cpu-----
r b swpd free buff cache si so bi bo in cs us sy id wa st
0 0 0 2785 12 236 0 0 5 126 57 279 0 0 99 0 0
0 0 0 2785 12 236 0 0 0 0 5802 29064 0 2 98 0 0
0 0 0 2785 12 236 0 0 0 0 5575 27924 0 3 97 0 0
0 0 0 2785 12 236 0 0 0 0 5579 27956 0 3 97 0 0
0 0 0 2785 12 236 0 0 0 6 5666 28378 0 3 97 0 0

yashwin@YASHWIN-ENAMADI:~$ sar -u
Cannot open /var/log/sysstat/sa20: No such file or directory
Please check if data collecting is enabled
yashwin@YASHWIN-ENAMADI:~$ sar -u 2 5
Linux 4.19.104-microsoft-standard (YASHWIN-ENAMADI) 08/20/20 _x86_64_ (8 CPU)

00:22:53 CPU %user %nice %system %iowait %steal %idle
00:22:55 all 0.00 0.00 3.37 0.00 0.00 96.63
00:22:57 all 0.25 0.00 2.94 0.00 0.00 96.81
00:22:59 all 0.19 0.00 2.15 0.00 0.00 97.67
00:23:01 all 0.06 0.00 3.13 0.00 0.00 96.81
00:23:03 all 0.19 0.00 3.13 0.00 0.00 96.69
Average: all 0.14 0.00 2.94 0.00 0.00 96.92

```

We see that there are large number of context switches happening, during the execution of the process. These are due to the process accessing the disk quite often. So, disk access is the bottleneck of this process.

3.

cpu:

```

yashwin@YASHWIN-ENAMADI:~$ vmstat -S M 2 5
procs -----memory-----swap-----io-----system-- -----cpu-----
r b swpd free buff cache si so bi bo in cs us sy id wa st
1 0 0 2785 12 237 0 0 5 109 85 387 0 0 99 0 0
1 0 0 2785 12 237 0 0 0 13 24 12 0 0 87 0 0
1 0 0 2785 12 237 0 0 0 15 27 12 0 0 87 0 0
1 0 0 2785 12 237 0 0 0 11 22 12 0 0 87 0 0
1 0 0 2785 12 237 0 0 0 11 23 12 0 0 87 0 0

yashwin@YASHWIN-ENAMADI:~$ sar -u 2 5
Linux 4.19.104-microsoft-standard (YASHWIN-ENAMADI) 08/20/20 _x86_64_ (8 CPU)

00:33:08 CPU %user %nice %system %iowait %steal %idle
00:33:10 all 12.48 0.00 0.12 0.00 0.00 87.39
00:33:12 all 12.53 0.00 0.19 0.00 0.00 87.28
00:33:14 all 12.54 0.00 0.12 0.00 0.00 87.34
00:33:16 all 12.49 0.00 0.12 0.00 0.00 87.38
00:33:18 all 12.48 0.00 0.12 0.00 0.00 87.39
Average: all 12.51 0.00 0.14 0.00 0.00 87.36

```

User time : 12

Sys time : 0

cpu-print:

```

yashwin@YASHWIN-ENAMADI:~$ vmstat -S M 2 5
procs -----memory-----swap-----io-----system-- -----cpu-----
r b swpd free buff cache si so bi bo in cs us sy id wa st
1 0 0 2785 12 237 0 0 5 118 76 366 0 0 99 0 0
0 0 0 2785 12 237 0 0 0 0 15227 49803 0 6 93 0 0
0 0 0 2785 12 237 0 0 0 0 13846 46698 0 6 93 0 0
0 0 0 2785 12 237 0 0 0 0 16083 53258 1 6 94 0 0
0 0 0 2785 12 237 0 0 0 0 15652 53069 0 7 92 0 0

yashwin@YASHWIN-ENAMADI:~$ sar -u 2 5
Linux 4.19.104-microsoft-standard (YASHWIN-ENAMADI) 08/20/20 _x86_64_ (8 CPU)

00:26:32 CPU %user %nice %system %iowait %steal %idle
00:26:34 all 0.50 0.00 6.30 0.00 0.00 93.20
00:26:36 all 0.62 0.00 7.29 0.00 0.00 92.09
00:26:38 all 0.44 0.00 6.30 0.00 0.00 93.26
00:26:40 all 0.31 0.00 6.46 0.00 0.00 93.22
00:26:42 all 0.38 0.00 5.32 0.00 0.00 94.30
Average: all 0.45 0.00 6.34 0.00 0.00 93.21

```

User time : 1

Sys time : 7

disk:

```

yashwin@YASHWIN-ENAMADI:~$ vmstat -S M 2 5
procs -----memory-----swap-----io-----system-- -----cpu-----
r b swpd free buff cache si so bi bo in cs us sy id wa st
1 0 0 2786 12 237 0 0 4 84 68 311 0 0 99 0 0
1 0 0 2786 12 237 0 0 0 13 21 13 0 0 87 0 0
1 0 0 2786 12 237 0 0 0 10 20 13 0 0 88 0 0
1 0 0 2786 12 237 0 0 0 10 19 13 0 0 88 0 0
1 0 0 2786 12 237 0 0 0 11 20 12 0 0 87 0 0

yashwin@YASHWIN-ENAMADI:~$ sar -u 2 5
Linux 4.19.104-microsoft-standard (YASHWIN-ENAMADI) 08/20/20 _x86_64_ (8 CPU)

00:57:17 CPU %user %nice %system %iowait %steal %idle
00:57:19 all 12.48 0.00 0.12 0.00 0.00 87.39
00:57:21 all 12.51 0.00 0.00 0.00 0.00 87.49
00:57:23 all 12.50 0.00 0.00 0.00 0.00 87.50
00:57:25 all 12.48 0.00 0.06 0.00 0.00 87.45
00:57:27 all 12.50 0.00 0.00 0.00 0.00 87.50
Average: all 12.50 0.00 0.04 0.00 0.00 87.47

```

User time : 13

Sys time : 0

disk1:

```

yashwin@YASHWIN-ENAMADI:~$ vmstat -S M 2 5
procs -----memory-----swap-----io-----system-- -----cpu-----
r b swpd free buff cache si so bi bo in cs us sy id wa st
0 0 0 2785 12 236 0 0 5 126 57 279 0 0 99 0 0
0 0 0 2785 12 236 0 0 0 0 5802 29064 0 2 98 0 0
0 0 0 2785 12 236 0 0 0 0 5575 27924 0 3 97 0 0
0 0 0 2785 12 236 0 0 0 0 5579 27956 0 3 97 0 0
0 0 0 2785 12 236 0 0 0 6 5666 28378 0 3 97 0 0

yashwin@YASHWIN-ENAMADI:~$ sar -u
Cannot open /var/log/sysstat/sa20: No such file or directory
Please check if data collecting is enabled
yashwin@YASHWIN-ENAMADI:~$ sar -u 2 5
Linux 4.19.104-microsoft-standard (YASHWIN-ENAMADI) 08/20/20 _x86_64_ (8 CPU)

00:22:53 CPU %user %nice %system %iowait %steal %idle
00:22:55 all 0.00 0.00 3.37 0.00 0.00 96.63
00:22:57 all 0.25 0.00 2.94 0.00 0.00 96.81
00:22:59 all 0.19 0.00 2.15 0.00 0.00 97.67
00:23:01 all 0.06 0.00 3.13 0.00 0.00 96.81
00:23:03 all 0.19 0.00 3.13 0.00 0.00 96.69
Average: all 0.14 0.00 2.94 0.00 0.00 96.92

```

User time : 0

Sys time : 3

4.

<pre>yashwin@YASHWIN-ENAMADI:~\$ ps -A PID TTY          TIME CMD   1 ?             00:00:00 init   7 ?             00:00:00 init   8 ?             00:00:00 init   9 pts/0         00:00:00 bash  89 ?            00:00:00 init  90 ?            00:00:00 init  91 pts/1         00:00:00 bash 104 pts/0         00:00:11 cpu 105 pts/1         00:00:00 ps yashwin@YASHWIN-ENAMADI:~\$ grep ctxt /proc/104/status voluntary_ctxt_switches:      15 nonvoluntary_ctxt_switches:    2</pre> <p>This process (cpu) involves only computation and hence there are significant nonvoluntary context switches as the OS interrupts the process to give space to other processes as well.</p>	<pre>yashwin@YASHWIN-ENAMADI:~\$ ps -A PID TTY          TIME CMD   1 ?             00:00:00 init   7 ?             00:00:00 init   8 ?             00:00:00 init   9 pts/0         00:00:00 bash  89 ?            00:00:00 init  90 ?            00:00:00 init  91 pts/1         00:00:00 bash 113 pts/0         00:00:00 disk 114 pts/1         00:00:00 ps yashwin@YASHWIN-ENAMADI:~\$ grep ctxt /proc/113/status voluntary_ctxt_switches:      17570 nonvoluntary_ctxt_switches:    0</pre> <p>This process (disk) reads from the disk regularly. So, whenever it accesses the disk, it voluntarily makes a context switch. Hence, there is no any need for the OS to interrupt the process.</p>
---	---

5. The pid for the bash shell is 9

```
yashwin@YASHWIN-ENAMADI:~$ ps -A
PID TTY          TIME CMD
  1 ?             00:00:00 init
  7 ?             00:00:00 init
  8 ?             00:00:00 init
  9 pts/0         00:00:00 bash
 89 pts/0         00:00:00 ps
```

The output for the pstree command is as follows :

```
yashwin@YASHWIN-ENAMADI:~$ pstree
init--init--init--bash--pstree
  |
  {init}
```

Initially, the init process with pid = 1, is created. It has two children as shown above. Process with pid = 1 has a child with pid = 7 and this inturn has a child with pid = 8 and this child with pid = 8 creates the bash shell (pid = 9)

6. The pid of cpu-print is 106

```
yashwin@YASHWIN-ENAMADI:~$ ps -A
PID TTY          TIME CMD
  1 ?             00:00:00 init
  7 ?             00:00:00 init
  8 ?             00:00:00 init
  9 pts/0         00:00:00 bash
 90 ?            00:00:00 init
 91 ?             00:00:00 init
 92 pts/1         00:00:00 bash
106 pts/0         00:00:08 cpu-print
107 pts/1         00:00:00 ps
```

The file descriptors are as shown

```
yashwin@YASHWIN-ENAMADI:~$ ls -l /proc/106/fd
total 0
lrwx----- 1 yashwin yashwin 64 Aug 19 10:36 0 -> /dev/pts/0
l-wx----- 1 yashwin yashwin 64 Aug 19 10:36 1 -> /tmp/tmp.txt
lrwx----- 1 yashwin yashwin 64 Aug 19 10:36 2 -> /dev/pts/0
```

We issued the output redirection command “>” to the file /tmp/tmp.txt. So, the file descriptor 1, which usually points to stdout is changed to point to the mentioned file.

7. Here, we used inter-process communication. The pipe allows the output of the first command (./cpu-print) to be passed on to the input of the second command(grep hello).

The file descriptors are as shown :

```
yashwin@YASHWIN-ENAMADI:~$ ps -A
  PID TTY          TIME CMD
    1 ?            00:00:00 init
    7 ?            00:00:00 init
    8 ?            00:00:00 init
    9 pts/0        00:00:01 bash
   90 ?            00:00:00 init
   91 ?            00:00:00 init
   92 pts/1        00:00:00 bash
  121 pts/0        00:00:07 cpu-print
  122 pts/0        00:00:04 grep
  123 pts/1        00:00:00 ps
yashwin@YASHWIN-ENAMADI:~$ ls -l /proc/121/fd
total 0
lrwx----- 1 yashwin yashwin 64 Aug 19 10:49 0 -> /dev/pts/0
l-wx----- 1 yashwin yashwin 64 Aug 19 10:49 1 -> 'pipe:[14624]'
lrwx----- 1 yashwin yashwin 64 Aug 19 10:49 2 -> /dev/pts/0
yashwin@YASHWIN-ENAMADI:~$ ls -l /proc/122/fd
total 0
lr-x----- 1 yashwin yashwin 64 Aug 19 10:49 0 -> 'pipe:[14624]'
lrwx----- 1 yashwin yashwin 64 Aug 19 10:49 1 -> /dev/pts/0
lrwx----- 1 yashwin yashwin 64 Aug 19 10:49 2 -> /dev/pts/0
```