Gebze Technical University

Departman of Computer Engineering

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HW5 Report

GONCA EZGİ ÇAKIR

151044054

1. Solution Approach

In summary, this program is implemented as directory copying utility (works like cp -R sourcePath destinationPath command) Program has a producer consumer mechanism that shares a buffer space in order to copy all the content from source path to destination path. This utility is handled by a thread pool that is synchronized by semaphores and mutex.

1.1. Main Program

Main program provides the healthy environment for the program.

Main program steps are listed below.

- Main program takes arguments from user by **./pCp bufferSize numOfConsumer sourcePath DestinationPath** command.
- Signal handler set in order to handle SIGINT when a ctrl-c input received, it frees all resources and threads.
- Set all statistics variables (numFile, numFifo, numDirectory, totalLoadedByte) and done flag to zero at the beginning.
- Dynamically allocates space for the buffer according to given size then initializes the buffer. (This buffer works as a queue in order to handle files in organizetion.)
- Initializes semaphores and mutex in order to handle synchronization.
- Before creating the threads stores the time by using **gettimeofday.**
- Creates producer thread and passes the soruce and destination paths as an array toScreenshot from 2023-06-03 23-51-55 the thread, stores thread id.
- Creates worker thread pool in a loop that iterates according to given number of consumers, stores thread ids.
- At the end frees all allocated resources, closes files,prnts the statistic of the program and **joins** all threads then exits successfully.

Error Handling

- Given number of command arguments checked, if it is less than 5 it prints the error message with an usage information and exits.
- Given buffer size or number of consumer is less then zero it prints the error message with an usage information and exits.

Screenshot from 2023-06-03 23-51-55

1.2. Producer Thread

Producer thread mainly produces the file information that is need to by loaded from source path to destination path. It adds the related item information to the buffer then notifies consumers to take these items and load their content properly.

Producer thread working mechanism is listed below.

- Firstly checks that given destination directory is exist or not. If it doesn't exist it creates it otherwise just opens the directory.
- Then looks into directory content and it goes recursively in order to handle all sub directories. (For this **listFiles** helper function is implemented.)
- Before adding an item into buffer locks the *mutex* and unlocks it after it is added. Also waits (decremnets) *empty* semaphore before adding the item into buffer and posts(incerements) *full* semaphore after it is added.
- If the item is directory and if it is not occurs at the given destination it is created, otherwise just opened.
- If the item is file its source path and the destination path is checked for any errors. If everything works properly file descriptors, paths and file name is stored in a struct BufferItem and added into the buffer.
- After finished searching all directories recursively it sets the *done* flag to 1.

1.3. Consumer Thread

Consumer thread mainly loads the file contents from source path to destination path. It basiclt gets an item from buffer and reads the file content from source and write into destination.

Consumer thread working mechanism is listed below.

- Consumer iterates in a loop in order to get new item from buffer until the done flag is set to 1 or the current buffer size is greater than 0.
- It wait for full semaphore to increment in order to be notifed that there is an item in the buffer, otherwise consumer shouldn't be consuming anything.
- It locks the mutex before removing an item from buffer and unlocks it after it is removed.
- Then empty semophore is posted in order to notify the producer that an item from buffer is consumed.
- Later file information (file descriptors, file paths, filename) is got from BufferItem struct and the content is loaded. (For this **loadFile** helper function is implemented.)

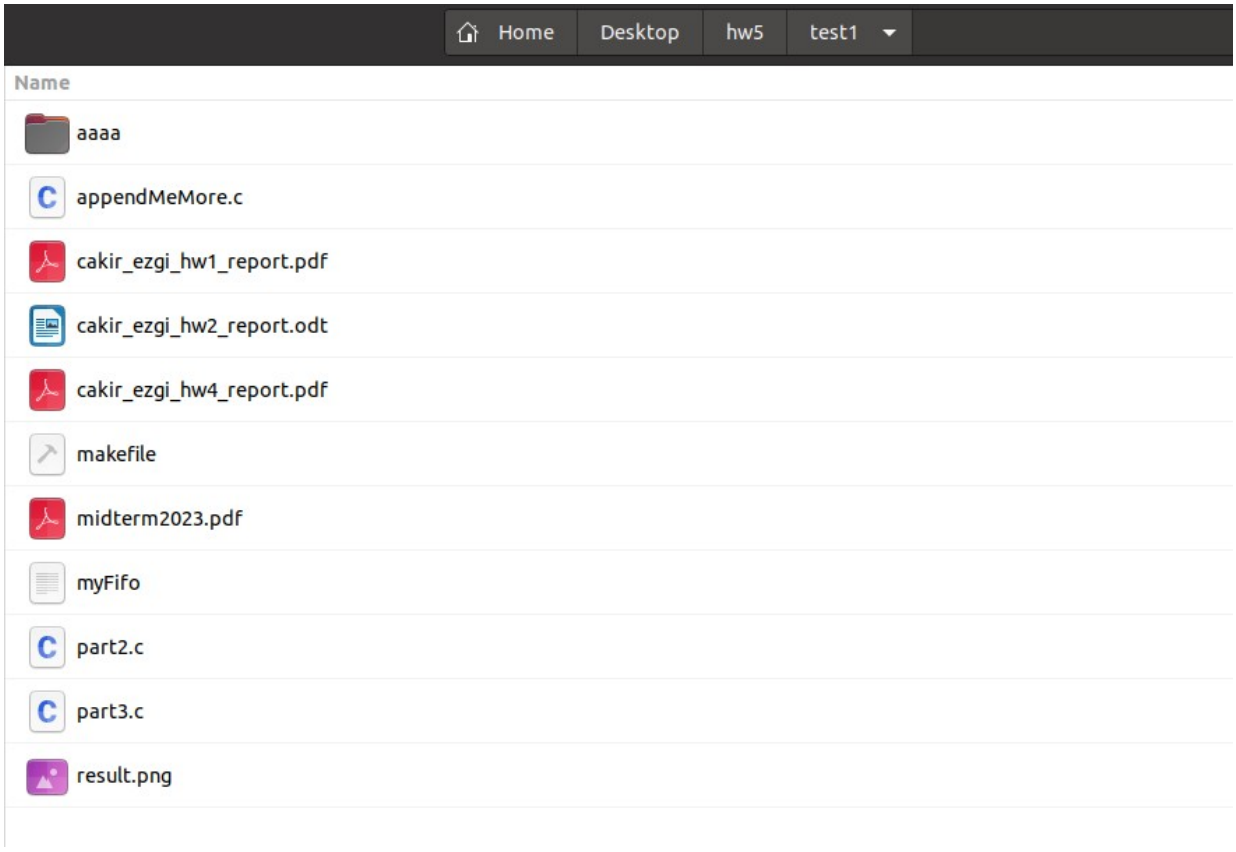
Semaphore and Mutex Usage

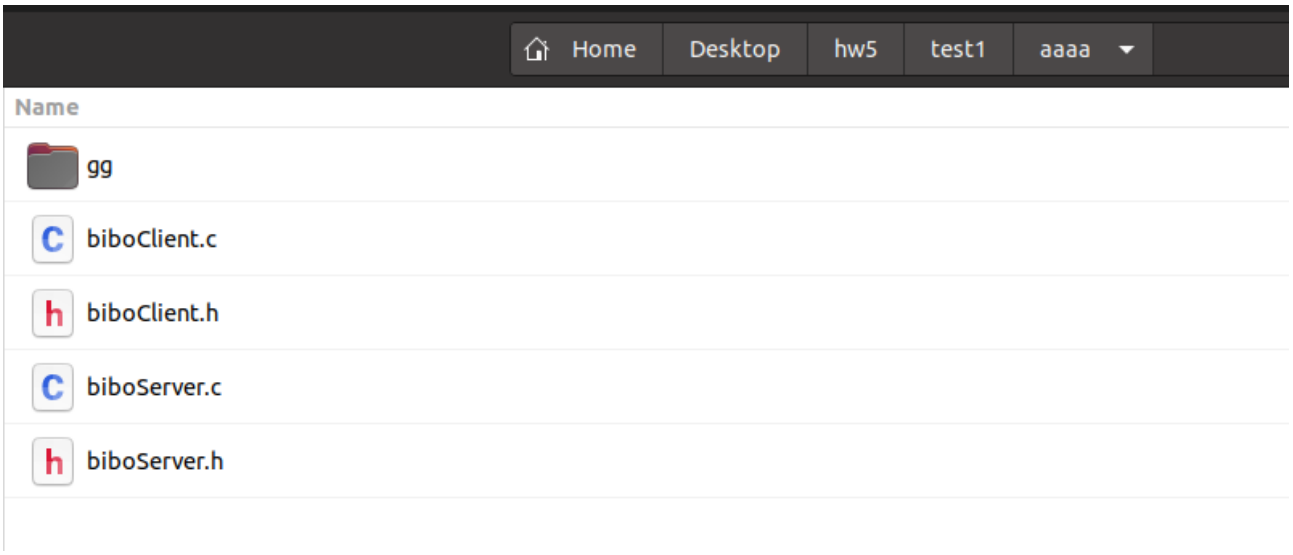
- **print, empty, full, mutex**
- Counting semaphore *empty* is set to bufferSize amount at the beginning; called *sem_wait()* each time a producer added an item into buffer and and called *sem_post()* when a consumer removed an item from buffer.
- Counting semaphore *full* is set to 0 amount at the beginning; called *sem_wait()* each time a consumer removed an item from buffer and and called *sem_post()* when a producer added an item to buffer.
- Binary semaphore *print* is set to 1 amount at the beginning; called *sem_wait()* each time before anything printinf on terminal and called *sem_post()* after.
- Mutex *mutex* is initialized at the beginning of the program and locked before adding or removing an item to buffer and unlocks afterwards. By this mutex the shared sapec between threads is protected.

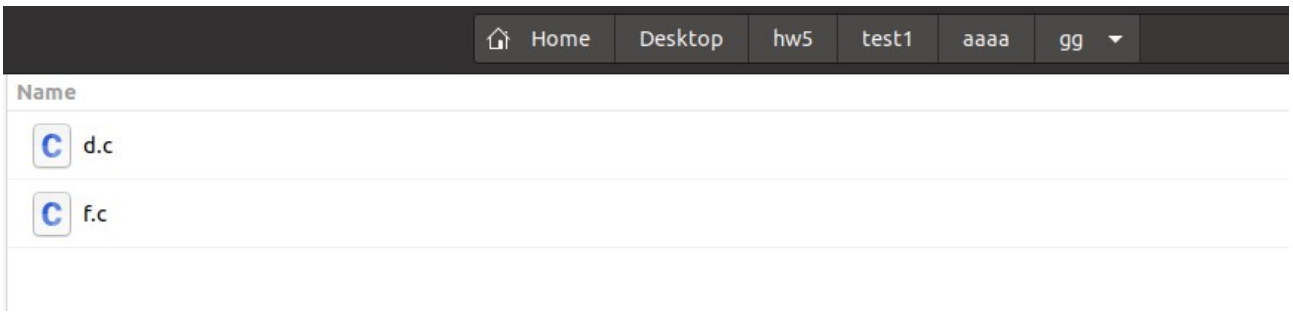
2. Test Results

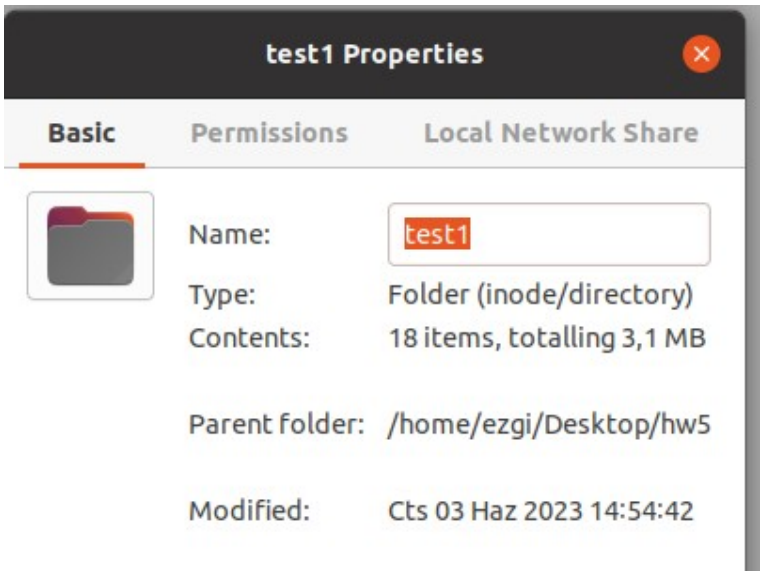
Multiple test case senarios applied and screenshots are added. Below you will see some program results.

Test File Content




Home
Desktop
hw5
test1
aaaa
Name
gg
biboClient.c
biboClient.h
biboServer.c
biboServer.h


Home
Desktop
hw5
test1
aaaa
gg
Name
d.c
f.c


test1 Properties
Basic
Permissions
Local Network Share
Name:
test1
Type:
Folder (inode/directory)
Contents:
18 items, totalling 3,1 MB
Parent folder:
/home/ezgi/Desktop/hw5
Modified:
Cts 03 Haz 2023 14:54:42

2.1. Buffer size is greater than number of consumers

```
ezgi@ezgi-Lenovo-ThinkBook-16p-Gen-2:~/Desktop/hw5$ ./pCp 47 8 test1 test2
Buffer created with size 47.
Thread pool is creating with size 8.
Directory 'test2' is created. [0 bytes]
Consumer 0 is created.
Consumer 3 is created.
Directory 'test1' is created. [4096 bytes]
Producer is created.
Consumer 1 is created.
Consumer 4 is created.
Consumer 5 is created.
Consumer 2 is created.
Consumer 6 is created.
Consumer 7 is created.
Consumer 3 loaded the file makefile. [253 bytes]
Consumer 3 loaded the file appendMeMore.c. [2112 bytes]
Consumer 1 loaded the file result.png. [26184 bytes]
Fifo 'myFifo' is loaded. [0 bytes]
Consumer 5 loaded the file part3.c. [2186 bytes]
Consumer 6 loaded the file part2.c. [3249 bytes]
Directory 'aaaa' is created. [4096 bytes]
Consumer 3 loaded the file biboServer.h. [3425 bytes]
Consumer 3 loaded the file biboClient.h. [694 bytes]
Directory 'gg' is created. [4096 bytes]
Consumer 3 loaded the file biboServer.c. [37032 bytes]
Consumer 5 loaded the file biboClient.c. [7193 bytes]
Consumer 7 loaded the file midterm2023.pdf. [173638 bytes]
Producer finished.
Consumer 1 loaded the file d.c. [7193 bytes]
Consumer 1 is finished.
Consumer 7 loaded the file f.c. [7193 bytes]
Consumer 3 is finished.
Consumer 5 is finished.
Consumer 7 is finished.
Consumer 4 is finished.
Consumer 0 loaded the file cakir_ezgi_hw1_report.pdf. [464193 bytes]
Consumer 0 is finished.
Consumer 6 loaded the file cakir_ezgi_hw2_report.odt. [480124 bytes]
Consumer 6 is finished.
Consumer 2 loaded the file cakir_ezgi_hw4_report.pdf. [1899522 bytes]
Consumer 2 is finished.


------------ SUMMARY ------------
Number of loaded fifo -> 1
Number of loaded directory -> 4
Number of loaded file -> 15
Total bytes loaded -> 3126479
Total time taken: 7.401000 ms
---------------------------------

ezgi@ezgi-Lenovo-ThinkBook-16p-Gen-2:~/Desktop/hw5$
```

2.2. Number of consumers is greater than buffer size

```
ezgi@ezgi-Lenovo-ThinkBook-16p-Gen-2:~/Desktop/hw5$ ./pCp 1 20 test1 test3
Buffer created with size 1.
Thread pool is creating with size 20.
Directory 'test3' is created. [0 bytes]
Directory 'test1' is created. [4096 bytes]
Producer is created.
Consumer 1 is created.
Consumer 2 is created.
Consumer 3 is created.
Consumer 0 is created.
Consumer 0 loaded the file makefile. [253 bytes]
Consumer 4 is created.
Consumer 1 loaded the file appendMeMore.c. [2112 bytes]
Fifo 'myFifo' is loaded. [0 bytes]
Consumer 0 loaded the file part3.c. [2186 bytes]
Consumer 3 loaded the file result.png. [26184 bytes]
Consumer 5 is created.
Consumer 6 is created.
Consumer 5 loaded the file part2.c. [3249 bytes]
Directory 'aaaa' is created. [4096 bytes]
Consumer 8 is created.
Consumer 1 loaded the file biboServer.h. [3425 bytes]
Consumer 9 is created.
Consumer 7 is created.
Consumer 8 loaded the file biboClient.h. [694 bytes]
Consumer 1 loaded the file biboClient.c. [7193 bytes]
Consumer 11 is created.
Directory 'gg' is created. [4096 bytes]
Consumer 5 loaded the file midterm2023.pdf. [173638 bytes]
Consumer 10 is created.
Consumer 6 loaded the file biboServer.c. [37032 bytes]
Consumer 12 is created.
Producer finished.
Consumer 9 loaded the file d.c. [7193 bytes]
Consumer 9 is finished.
Consumer 7 is finished.
Consumer 1 is finished.
Consumer 12 loaded the file f.c. [7193 bytes]
Consumer 8 is finished.
Consumer 14 is created.
Consumer 5 is finished.
Consumer 10 is finished.
Consumer 3 is finished.
Consumer 15 is created.
Consumer 15 is finished.
Consumer 6 is finished.
Consumer 12 is finished.
Consumer 16 is created.
Consumer 14 is finished.
Consumer 13 is created.
Consumer 13 is finished.
Consumer 18 is created.
Consumer 18 is finished.
Consumer 11 is finished.
Consumer 17 is created.
Consumer 17 is finished.
Consumer 16 is finished.
Consumer 19 is created.
Consumer 19 is finished.
Consumer 2 loaded the file cakir_ezgi_hw1_report.pdf. [464193 bytes]
```

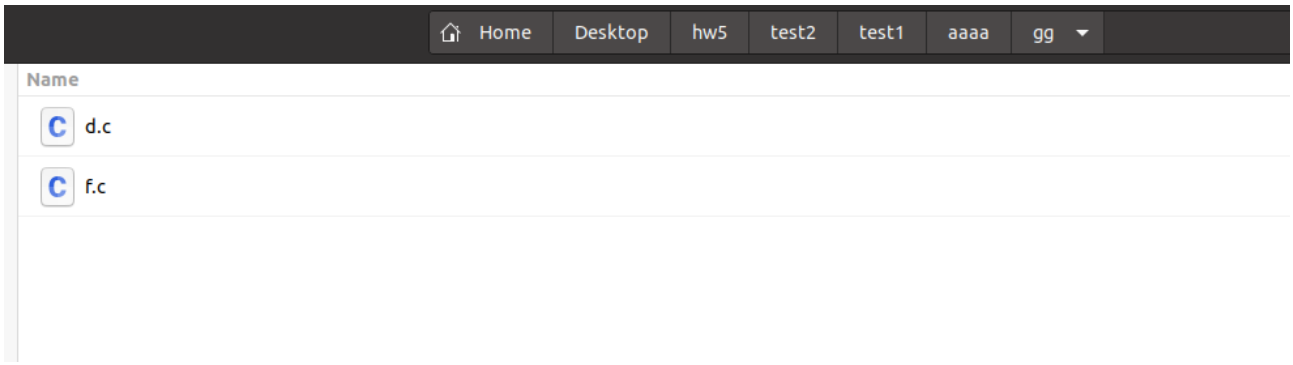
```
Consumer 19 is finished.
Consumer 2 loaded the file cakir_ezgi_hw1_report.pdf. [464193 bytes]
Consumer 2 is finished.
Consumer 0 loaded the file cakir_ezgi_hw2_report.odt. [480124 bytes]
Consumer 0 is finished.
Consumer 4 loaded the file cakir_ezgi_hw4_report.pdf. [1899522 bytes]
Consumer 4 is finished.


------------ SUMMARY ------------
Number of loaded fifo -> 1
Number of loaded directory -> 4
Number of loaded file -> 15
Total bytes loaded -> 3126479
Total time taken: 7.249000 ms
---------------------------------

ezgi@ezgi-Lenovo-ThinkBook-16p-Gen-2:~/Desktop/hw5$
```

2.3. Buffer size is equal to number of consumers

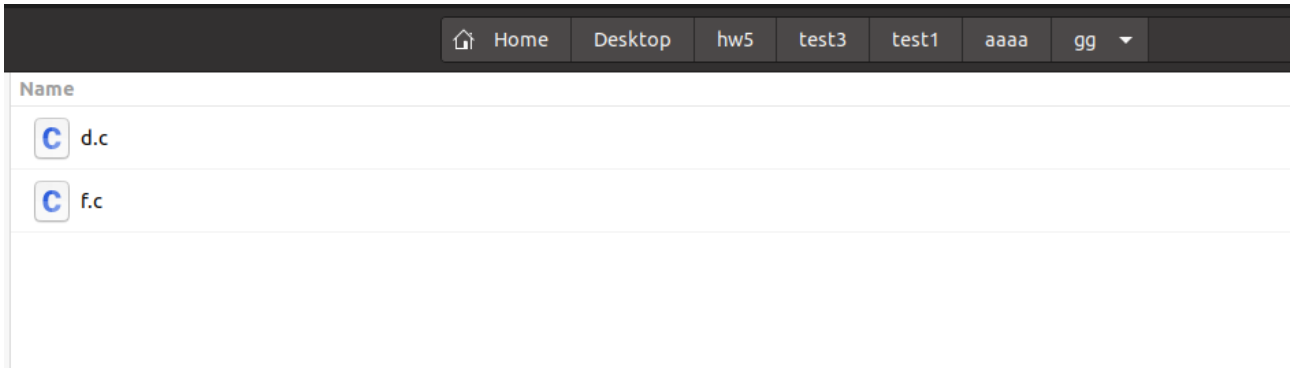
```
ezgi@ezgi-Lenovo-ThinkBook-16p-Gen-2:~/Desktop/hw5$ ./pCp 10 10 test1 test4
Buffer created with size 10.
Thread pool is creating with size 10.
Directory 'test4' is created. [0 bytes]
Consumer 1 is created.
Directory 'test1' is created. [4096 bytes]
Producer is created.
Consumer 0 is created.
Consumer 2 is created.
Consumer 3 is created.
Consumer 4 is created.
Consumer 1 loaded the file makefile. [253 bytes]
Fifo 'myFifo' is loaded. [0 bytes]
Consumer 0 loaded the file appendMeMore.c. [2112 bytes]
Consumer 2 loaded the file part3.c. [2186 bytes]
Consumer 6 is created.
Consumer 4 loaded the file result.png. [26184 bytes]
Consumer 0 loaded the file part2.c. [3249 bytes]
Consumer 5 is created.
Consumer 7 is created.
Consumer 8 is created.
Directory 'aaaa' is created. [4096 bytes]
Consumer 9 is created.
Consumer 4 loaded the file biboServer.h. [3425 bytes]
Consumer 4 loaded the file biboClient.h. [694 bytes]
Directory 'gg' is created. [4096 bytes]
Consumer 5 loaded the file biboServer.c. [37032 bytes]
Consumer 7 loaded the file biboClient.c. [7193 bytes]
Producer finished.
Consumer 8 loaded the file d.c. [7193 bytes]
Consumer 8 is finished.
Consumer 0 is finished.
Consumer 4 is finished.
Consumer 9 loaded the file f.c. [7193 bytes]
Consumer 9 is finished.
Consumer 5 is finished.
Consumer 7 is finished.
Consumer 6 loaded the file midterm2023.pdf. [173638 bytes]
Consumer 6 is finished.
Consumer 3 loaded the file cakir_ezgi_hw1_report.pdf. [464193 bytes]
Consumer 3 is finished.
Consumer 2 loaded the file cakir_ezgi_hw2_report.odt. [480124 bytes]
Consumer 2 is finished.
Consumer 1 loaded the file cakir_ezgi_hw4_report.pdf. [1899522 bytes]
Consumer 1 is finished.


------------ SUMMARY ------------
Number of loaded fifo -> 1
Number of loaded directory -> 4
Number of loaded file -> 15
Total bytes loaded -> 3126479
Total time taken: 6.242000 ms
---------------------------------

ezgi@ezgi-Lenovo-ThinkBook-16p-Gen-2:~/Desktop/hw5$
```

File contents after all executions

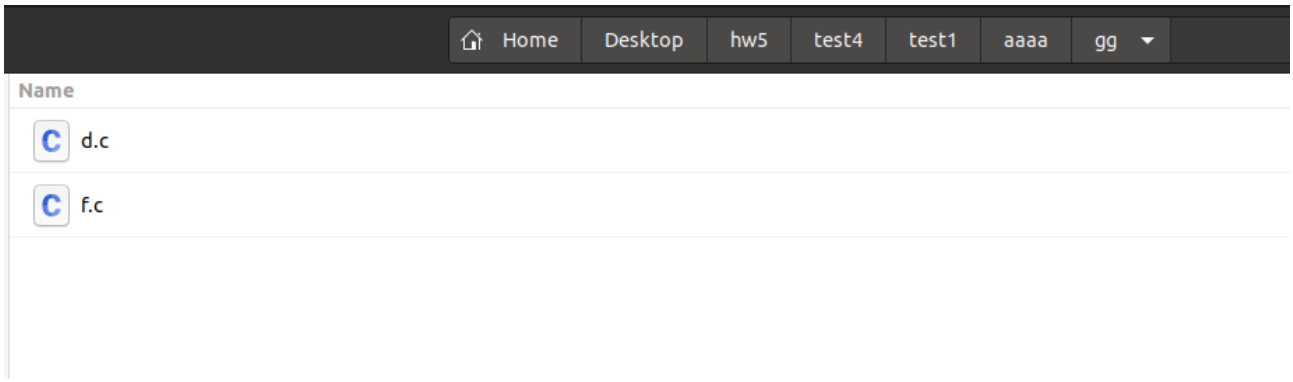
Test2 content - path



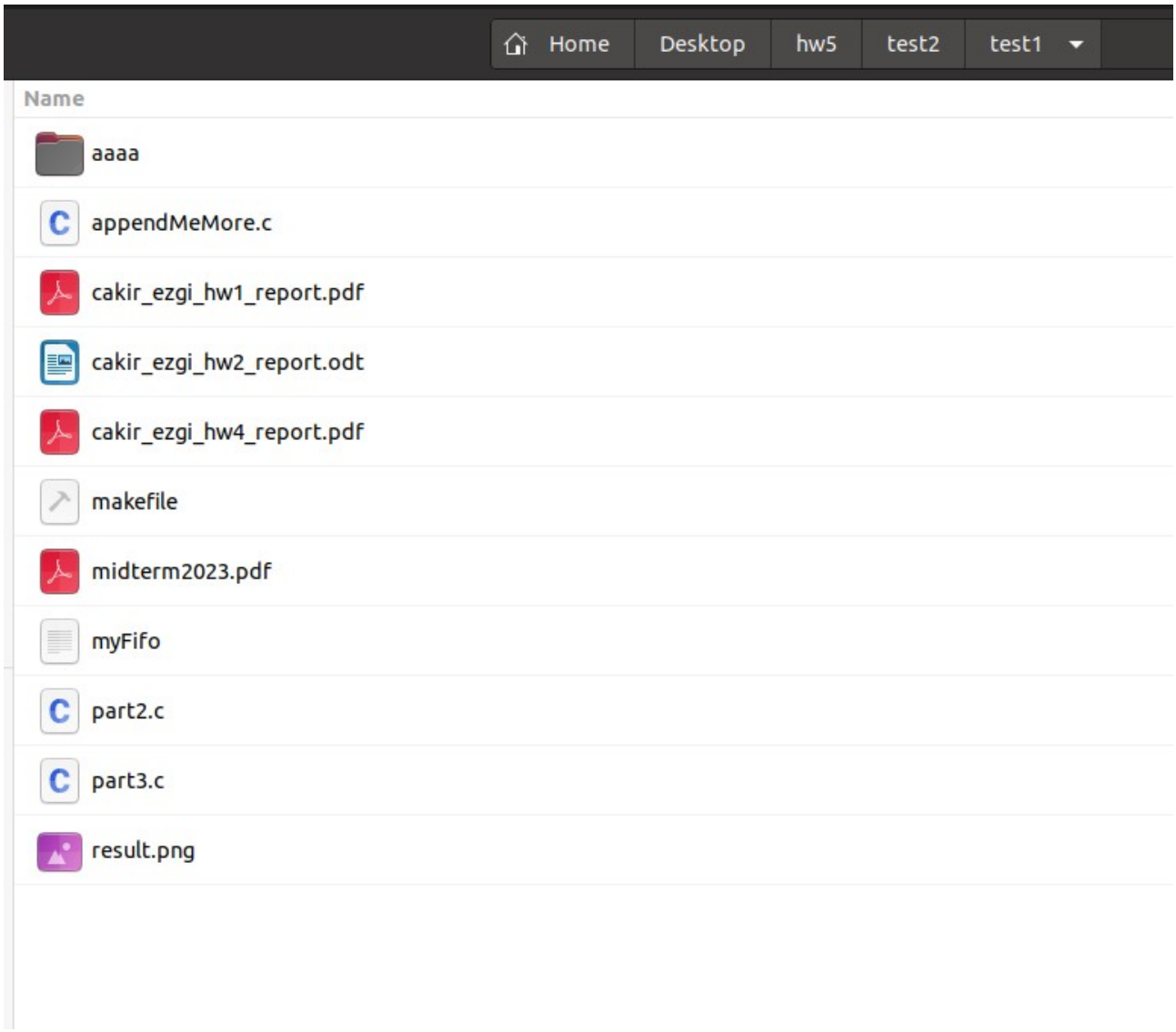
Test3 content - path



Test4 content - path



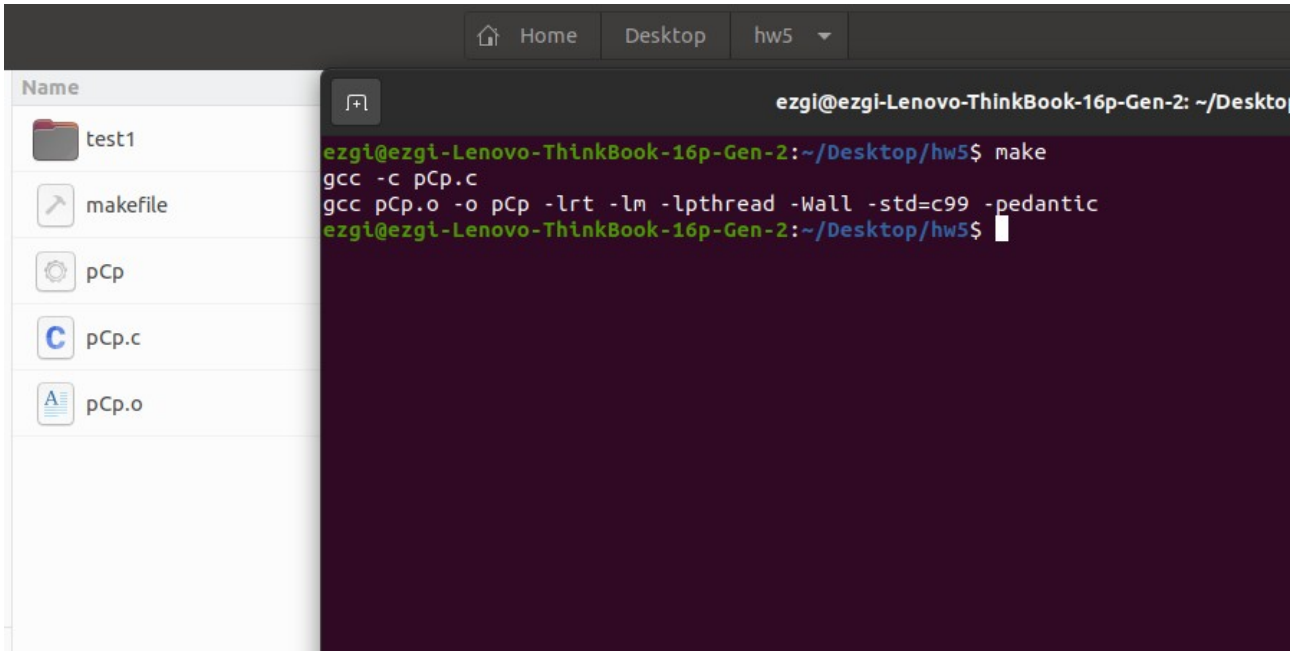
Example content (Test2 inside)



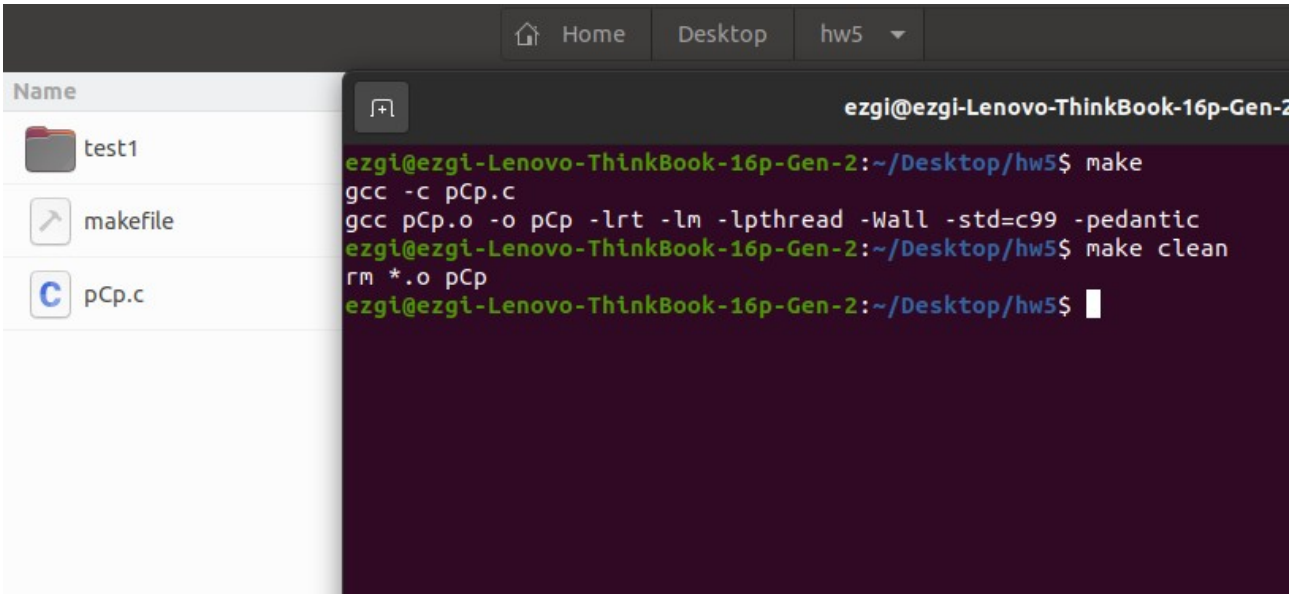
3. Makefile

You can see makefile content down below. It only complies the codes with warning flags by “make” command and cleans .o files with “make clean” command.

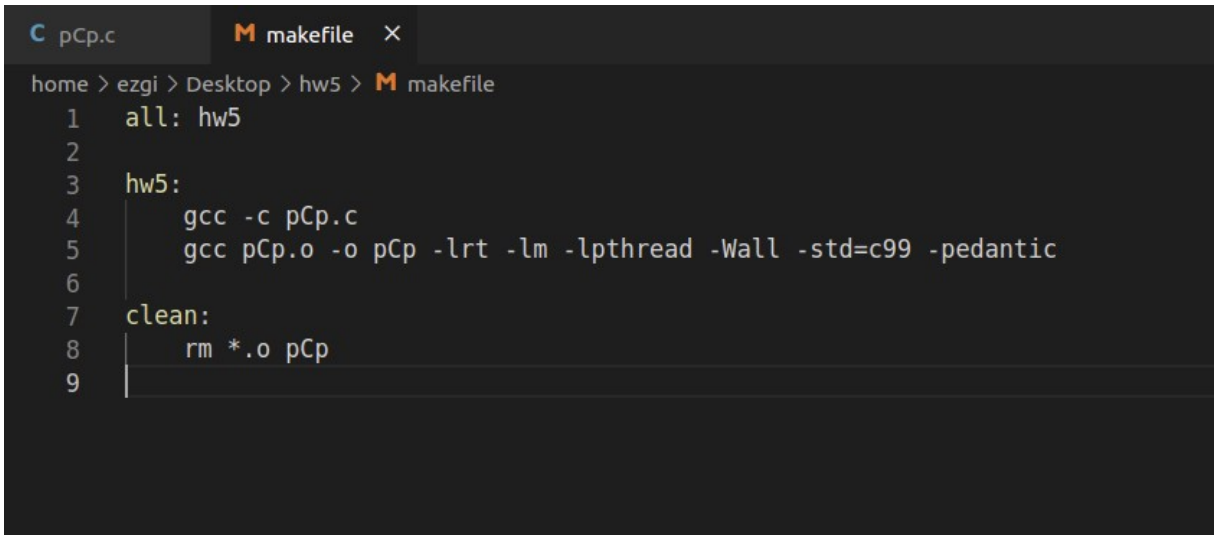
After make command



After “make clean” command



Makefile

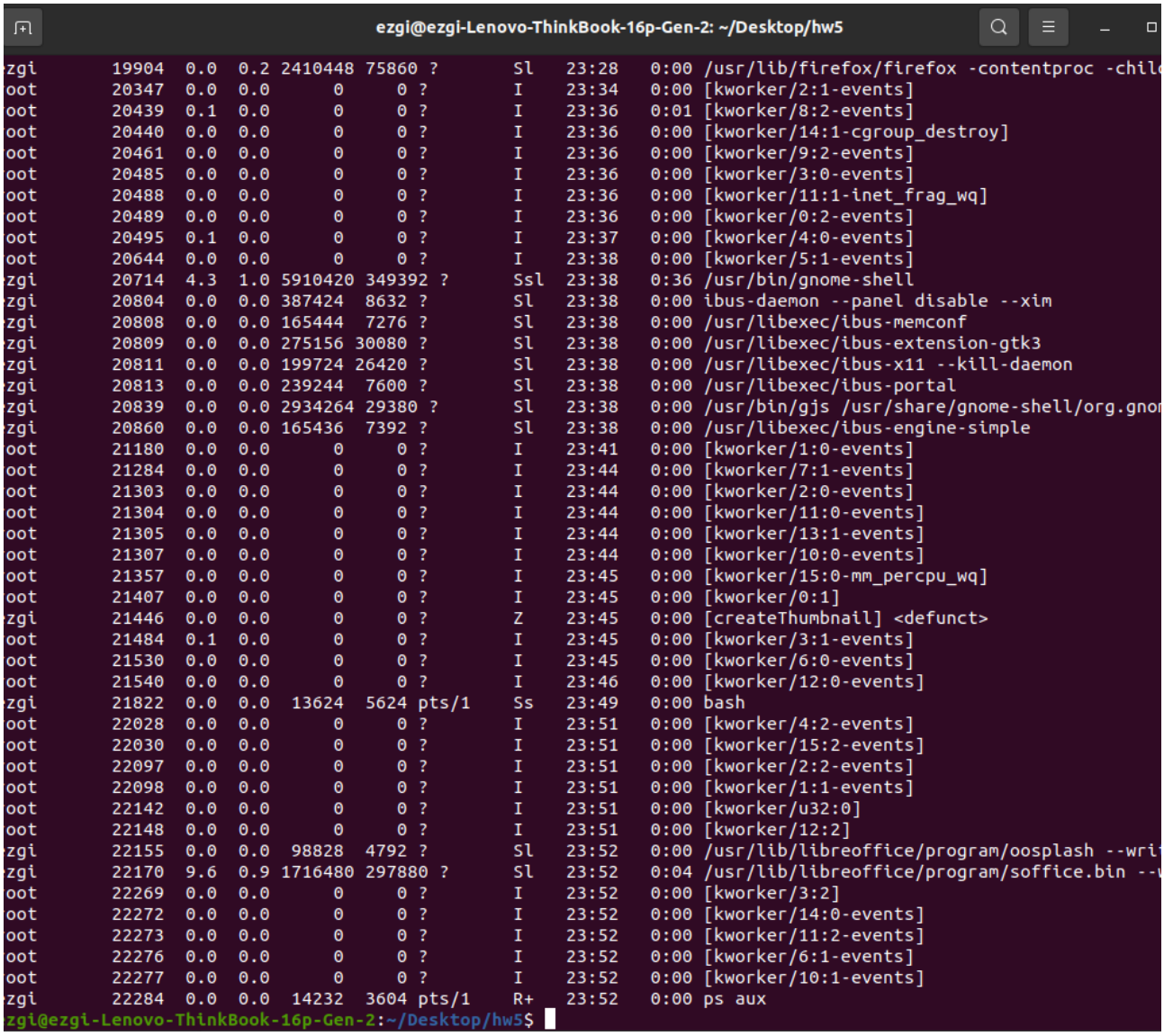


4. Valgrind – Leaks

valgrind

```
--22119-- REDIR: 0x4a03bd0 (libc.so.6:__strcmp_avx2) redirected to 0x483fed0 (strcmp)
Consumer 4 is created.
Consumer 1 loaded the file makefile. [253 bytes]
Consumer 3 loaded the file appendMeMore.c. [2112 bytes]
Consumer 4 loaded the file part3.c. [2186 bytes]
Consumer 3 loaded the file part2.c. [3249 bytes]
Consumer 1 loaded the file result.png. [26184 bytes]
Directory 'aaaa' is created. [4096 bytes]
Directory 'gg' is created. [4096 bytes]
Consumer 3 loaded the file biboServer.h. [3425 bytes]
Consumer 3 loaded the file biboClient.h. [694 bytes]
Producer finished.
Consumer 3 loaded the file biboServer.c. [37032 bytes]
Consumer 3 loaded the file biboClient.c. [7193 bytes]
Consumer 3 loaded the file d.c. [7193 bytes]
Consumer 3 loaded the file f.c. [7193 bytes]
Consumer 3 is finished.
Consumer 1 loaded the file midterm2023.pdf. [173638 bytes]
Consumer 1 is finished.
Consumer 2 loaded the file cakir_ezgi_hw1_report.pdf. [464193 bytes]
Consumer 2 is finished.
Consumer 0 loaded the file cakir_ezgi_hw2_report.odt. [480124 bytes]
Consumer 0 is finished.
Consumer 4 loaded the file cakir_ezgi_hw4_report.pdf. [1899522 bytes]
Consumer 4 is finished.


------------ SUMMARY ------------
Number of loaded fifo -> 0
Number of loaded directory -> 2
Number of loaded file -> 15
Total bytes loaded -> 3122383
--22119-- REDIR: 0x4a0b6e0 (libc.so.6:__memcpy_avx_unaligned_erms) redirected to 0x48429f0 (memmove)
Total time taken: 159.907000 ms
---------------------------------

==22119==
==22119== HEAP SUMMARY:
==22119==     in use at exit: 0 bytes in 0 blocks
==22119==   total heap usage: 17 allocs, 17 frees, 245,924 bytes allocated
==22119==
==22119== All heap blocks were freed -- no leaks are possible
==22119==
==22119== ERROR SUMMARY: 0 errors from 0 contexts (suppressed: 0 from 0)
ezgi@ezgi-Lenovo-ThinkBook-16p-Gen-2:~/Desktop/hw5$
```

ps aux


ezgi@ezgi-Lenovo-ThinkBook-16p-Gen-2: ~/Desktop/hw5
zgi 19904 0.0 0.2 2410448 75860 ? Sl 23:28 0:00 /usr/lib/firefox/firefox -contentproc -chil
oot 20347 0.0 0.0 0 0 ? I 23:34 0:00 [kworker/2:1-events]
oot 20439 0.1 0.0 0 0 ? I 23:36 0:01 [kworker/8:2-events]
oot 20440 0.0 0.0 0 0 ? I 23:36 0:00 [kworker/14:1-cgroup_destroy]
oot 20461 0.0 0.0 0 0 ? I 23:36 0:00 [kworker/9:2-events]
oot 20485 0.0 0.0 0 0 ? I 23:36 0:00 [kworker/3:0-events]
oot 20488 0.0 0.0 0 0 ? I 23:36 0:00 [kworker/11:1-inet_frag_wq]
oot 20489 0.0 0.0 0 0 ? I 23:36 0:00 [kworker/0:2-events]
oot 20495 0.1 0.0 0 0 ? I 23:37 0:00 [kworker/4:0-events]
oot 20644 0.0 0.0 0 0 ? I 23:38 0:00 [kworker/5:1-events]
zgi 20714 4.3 1.0 5910420 349392 ? Ssl 23:38 0:36 /usr/bin/gnome-shell
zgi 20804 0.0 0.0 387424 8632 ? Sl 23:38 0:00 ibus-daemon --panel disable --xim
zgi 20808 0.0 0.0 165444 7276 ? Sl 23:38 0:00 /usr/libexec/ibus-memconf
zgi 20809 0.0 0.0 275156 30080 ? Sl 23:38 0:00 /usr/libexec/ibus-extension-gtk3
zgi 20811 0.0 0.0 199724 26420 ? Sl 23:38 0:00 /usr/libexec/ibus-x11 --kill-daemon
zgi 20813 0.0 0.0 239244 7600 ? Sl 23:38 0:00 /usr/libexec/ibus-portal
zgi 20839 0.0 0.0 2934264 29380 ? Sl 23:38 0:00 /usr/bin/gjs /usr/share/gnome-shell/org.gno
zgi 20860 0.0 0.0 165436 7392 ? Sl 23:38 0:00 /usr/libexec/ibus-engine-simple
oot 21180 0.0 0.0 0 0 ? I 23:41 0:00 [kworker/1:0-events]
oot 21284 0.0 0.0 0 0 ? I 23:44 0:00 [kworker/7:1-events]
oot 21303 0.0 0.0 0 0 ? I 23:44 0:00 [kworker/2:0-events]
oot 21304 0.0 0.0 0 0 ? I 23:44 0:00 [kworker/11:0-events]
oot 21305 0.0 0.0 0 0 ? I 23:44 0:00 [kworker/13:1-events]
oot 21307 0.0 0.0 0 0 ? I 23:44 0:00 [kworker/10:0-events]
oot 21357 0.0 0.0 0 0 ? I 23:45 0:00 [kworker/15:0-mm_percpu_wq]
oot 21407 0.0 0.0 0 0 ? I 23:45 0:00 [kworker/0:1]
zgi 21446 0.0 0.0 0 0 ? Z 23:45 0:00 [createThumbnail] <defunct>
oot 21484 0.1 0.0 0 0 ? I 23:45 0:00 [kworker/3:1-events]
oot 21530 0.0 0.0 0 0 ? I 23:45 0:00 [kworker/6:0-events]
oot 21540 0.0 0.0 0 0 ? I 23:46 0:00 [kworker/12:0-events]
zgi 21822 0.0 0.0 13624 5624 pts/1 Ss 23:49 0:00 bash
oot 22028 0.0 0.0 0 0 ? I 23:51 0:00 [kworker/4:2-events]
oot 22030 0.0 0.0 0 0 ? I 23:51 0:00 [kworker/15:2-events]
oot 22097 0.0 0.0 0 0 ? I 23:51 0:00 [kworker/2:2-events]
oot 22098 0.0 0.0 0 0 ? I 23:51 0:00 [kworker/1:1-events]
oot 22142 0.0 0.0 0 0 ? I 23:51 0:00 [kworker/u32:0]
oot 22148 0.0 0.0 0 0 ? I 23:51 0:00 [kworker/12:2]
zgi 22155 0.0 0.0 98828 4792 ? Sl 23:52 0:00 /usr/lib/libreoffice/program/oosplash --wri
zgi 22170 9.6 0.9 1716480 297880 ? Sl 23:52 0:04 /usr/lib/libreoffice/program/soffice.bin --
oot 22269 0.0 0.0 0 0 ? I 23:52 0:00 [kworker/3:2]
oot 22272 0.0 0.0 0 0 ? I 23:52 0:00 [kworker/14:0-events]
oot 22273 0.0 0.0 0 0 ? I 23:52 0:00 [kworker/11:2-events]
oot 22276 0.0 0.0 0 0 ? I 23:52 0:00 [kworker/6:1-events]
oot 22277 0.0 0.0 0 0 ? I 23:52 0:00 [kworker/10:1-events]
zgi 22284 0.0 0.0 14232 3604 pts/1 R+ 23:52 0:00 ps aux
zgi@ezgi-Lenovo-ThinkBook-16p-Gen-2:~/Desktop/hw5$