Problem Set 5: Virtual Memory and I/O

Write your answers for all parts in a file named **ps5.pdf**. You can create this file using any text editor, then convert it to pdf.

I. Questions on Chapters 9—12

1. Assume that we have a demand-paged memory. The page table is held in registers. It takes 8 milliseconds to service a page fault if an empty frame is available or if the replaced paged is not modified and 20 milliseconds if the replaced page is modified. The memory access time is 100 nanoseconds. Assume that the page to be replaced is modified 70% of the time. What is the maximum acceptable page-fault rate for an effective access time of no more than 200 nanoseconds?

2. Consider the following page reference string:
   7, 2, 3, 1, 2, 5, 3, 4, 6, 7, 7, 1, 0, 5, 4, 6, 2, 3, 0, 1
   Assuming demand paging with three frames, how many page faults would occur for the following replacement algorithms?
   a) LRU
   b) FIFO
   c) Optimal

3. Consider a system where free space is kept in a free-space list.
   a) Suppose that the pointer to the free-space list is lost. Can the system reconstruct the free-space list? Explain your answer.
   b) Consider a file system similar to the one used by UNIX with indexed allocation. How many disk I/O operations might be required to read the contents of a small local file at /a/b/c? Assume that none of the disk blocks is currently being cached.
   c) Suggest a scheme to ensure that the pointer is never lost as a result of memory failure.

Practice Problems (do not submit)

Solving the following problems will help you better understand the materials and prepare for the final. All are from the textbook [OSC].

Virtual Memory (chapter 9): 9.15, 9.18, 9.22, 9.27, 9.28, 9.36.

Storage System (chapters 10-12): 10.11, 10.16, 11.10, 12.10, 12.15, 12.16.

II. Measuring I/O Time

In this exercise, you will measure the time it takes to write to an output device (either a terminal or disk). Compile and run the following program:

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>

#define NUM_OF_TIMES 1000000

int main(int argc, char *argv[])
{
   int j;
   for (j = 0; j < NUM_OF_TIMES; j++) {
          write(1,"x",1);
         // printf("x");
   }
   return 0;
}
```

The program writes 1,000,000 'x' to the standard output. We will use the command `time` to measure the time taken to execute a command. The `time` command returns three values: `real` indicates the actual time taken to run the command; `user` indicates the time CPU spent running the command; and `sys` indicates the time CPU spent running the kernel due to the command.

(1) Suppose that you have named your executable `a.out`. Run:

```
time ./a.out
time ./a.out > X
```

Note down the output of the commands above. Which one is faster? Writing to terminal or to disk?

(2) Now, change the statement that outputs 'x' from using `write` to `printf`, by commenting out the call to `write` and uncommenting the call to `printf`. Compile, and repeat the commands above.

```
time ./a.out
time ./a.out > Y
```

Note down the output of the two commands above. Which one is faster? Writing to terminal or to disk? Is the time taken by `printf` faster or slower than `write`?

(3) Investigate and explain the differences in the timing you see in writing to terminal and to disk, and in using `printf` and `write`. (Hint: `strace` might be useful here).

III. Research Question: OS Case Study

This question gives you a chance to put together everything you learned in the class by studying an actual operating system from various perspectives. Choose any operating system that you like. The standard Linux and Microsoft Windows that we covered in class are not eligible, but modified versions of them for special systems are acceptable.

You may consider operating systems for:

- mobile devices (e.g., phones and tablets)
- real time systems (i.e., systems that have strict timing requirements)
- embedded systems (e.g., IoTs (internet of things))
- cloud systems (i.e., support for virtualized resources, e.g., Xen hypervisor)

Study the operating system that you chose carefully. Write a report (4—5 pages) using the **template** posted on Canvas. Name the file as **caseStudy.pdf**.

Important: Your writing MUST be your own, no copying or paraphrasing from any source. You can include figures in your report, but they must be your own, not copied. You can recreate/change some figures.

IV. Deliverables

Submit ps5.pdf and caseStudy.pdf on Canvas.