CS 416 - OS Design - Sample Midterm Exam (Spring 2020)

Note, this is just a sample example for practice. The structure and the complexity of questions could change during the actual exam.

1. **Address space (15 points)**

a. Draw the process address space for both a single-threaded process and a multi-threaded process. **(5 points)**

b. Can heaps be shared among threads? If they can be shared, is it typically desirable to write programs that allow threads to share a single heap (why/why not)? Can stacks be shared among threads? Can stacks be shared among threads? If they can be shared, is it typically desirable to write programs that allow threads to share stacks (why/why not)? **(5 points)**

c. Check the following code snippet, where are the data variables and data structures are allocated? Does this code run correctly or not? The stack is shared between threads in the code snippet, which is stated as "NOT desirable" in the last question. Is it OK to do so? (why/why not) **(5 points)**

```
int arg_list[10], i;
pthread_t thread_id[10];

for (i = 0; i < 10; i++) {
   pthread_create(&thread_id[i], NULL, func_foo, &arg_list[i]);
}
sleep(100000);
/* This part of code is never reached. */
```

2. **Process control block (20 points)**

a. What is a process control block (PCB) and what are the components in a PCB? **(5 points)**

b. During a context switch from process 0 to process 1, which components needs to be updated in hardware to make process 1 run correctly? For your listed components, please put the following items in the right component class: CPU general registers, the CR3, the program counter, the stack pointer, file descriptors, process ID, thread ID, page fault counters, process user ID, and the process command line. **(10 points)**

c. During a context switch from thread 0 to thread 1, which items listed above need to be updated in hardware? **(5 points)**

3. **Page table (25 points)**

a. Assume that in a system with a 32-bit address space, the page size is 8 KBytes, the physical memory size is 1 GByte, and each entry of the page table requires 4 bytes. What is the minimum size of physical memory that needs to be allocated for a single-level linear page table? **(10 points)**

b. Mention one advantage of the inverted page table over a multi-level page table. In addition, mention one advantage of the multi-level page table over an inverted page table. **(5 points)**

c. Mention two advantages of small page sizes (e.g., 8 KBytes) over large page sizes (e.g., 1 MByte). In addition, mention two advantages of large page sizes over small page sizes. **(10 points)**

4. **Threading (15 points)**

a. The following code is a famous bug in a widely used open source database code **(10 points)**

```
Thread 1:
  if (thd->proc_info) {
  ...
  fputs(thd->proc_info, ...);
  ...
  }

Thread 2:
  thd->proc_info = NULL;
```

Explain the problem in the above code?

b. Right after executing the following code segment, how many scheduling entities the kernel will see in its scheduler when (a) kernel-level threads are used, (b) user-level threads are used? **(10 points)**

```
if (fork() != 0) {
  sleep(10000);
  /* Assume this part is never reached. */
}

if (fork() != 0) {
  exec(command, parameter);
  /* Assume this part is never reached. */
}

If (fork () != 0) {
  pthread_create();
  sleep(10000);
  /* Assume this part is never reached. */
```

```
}

for (i = 0; i < 5; i++) {
  pthread_create();
}
```

5. **Page Tables and TLB (25 points)**

a. What is the benefit of a multilevel page table versus a flat page table? **(5 points)**

b. How much of the virtual address space does one L4, L3, L2, and L1 page table level entry cover in a 64-bit address space? **(10 points)**

c. Swapping: Assume your memory (DRAM) can hold only 3 physical frames. The "Access" column in the table below shows the physical frame pages accessed. The hit (y/n) column shows whether physical frame access is a hit (present in DRAM) or miss (not present in DRAM and present in disk), and "Physical Frame Slots" column shows the physical frame numbers present in the DRAM. Use OPT swapping policy and fill the Hit (with Yes or No) and Physical frame slots. **(10 points)**

Physical Frame Access	Hit? Enter (Y/N) ?	Physical Frame Slots (Enter phys. frame number) Slot 1	Slot 2	Slot 3
1				
2				
3				
4				
1				
2				
3				
4				
3				
2				
1				

Figure 1: OPT Swapping