CS 471-001: Operating Systems
Spring 2017

Homework 3
Due date: Monday, April 24th, 11:59 pm

Grading, submission and late policy:

- You are expected to complete this homework **on your own** (not with a partner or in a group)
- The homework accounts for **4%** of your final grade
- Standard late policy applies - Late penalty for this homework will be 15% for each
- day. Submissions that are late by 3 days or more will not be accepted
- You will submit your assignment via Blackboard

Part I: True or False – mark the following as true of false [10 points]

1. [1 point] Consider a system using virtual memory. In order to maximize the CPU utilization, the kernel should admit more processes to the main memory if it observes that the current CPU utilization is low.

   True False

2. [1 point] In a memory reference, it is possible to have a TLB hit and a page fault.

   True False

3. [1 point] Both vfork() and copy-on-write (COW) allow faster process (child) creation from the parent process.

   True False

4. [1 point] If two processes open() a file F and start working on it, there will be two different entries for F in the system-wide open-file table.

   True False

5. [1 point] In local page replacement, when a page fault occurs, a process can select a frame from another process as the victim frame for replacement.

   True False

6. [1 point] When a page fault occurs, the process is moved to waiting state

   True False

7. [1 point] The full bootstrap loader program is stored on the ROM

True False

8. [1 point] RAID 2 requires more additional hard disks to store the error correction codes compared to RAID 3

   True False

9. [1 point] The second chance algorithm is in essence FIFO page replacement along with modify bit.

   True False

10. [1 point] Thrashing increases not only disk I/O activity but also overall CPU utilization

   True False

Part II: Multiple choice - circle the correct answer [18 points]

11. [3 points] When a page fault occurs and the page replacement algorithm selects a modified page as the victim, how many total number of I/O operations required
    a. 0
    b. 1
    c. 2
    d. 4

12. [3 points] If a page replacement algorithm is subject to the Belady's anomaly,
    a. The same program can take more time to execute with more memory
    b. The activity on the paging disk may increase if we run the same program with more memory
    c. The number of page faults may increase with the number of frames for the same memory reference string
    d. All of the above

13. [3 points] Which of the following is not true for segmentation?
    a. It eliminates external fragmentation
    b. It allows re-compiling of individual functions after modification
    c. It allows assigning different protection rules for different parts of address space
    d. It allows finer-granularity memory sharing among processes

14. [3 points] Consider an instruction within a certain instruction-set architecture (ISA) SUB R1, M2, R3. This instruction subtracts the contents of the memory location M2 (direct addressing) from the value in Register R1, and stores the result in Register R3. What is the maximum number of page faults that may be caused by this single instruction?
    a. 1
    b. 2
    c. 3

d. 4

15. [3 points] Average time to transfer a block of data from hard disk to main memory depends on
    a. How fast the arm can move to desired cylinder where block is located
    b. Rotation per minutes supported by the disk
    c. The transfer rate of the hard disk
    d. All of the above
16. [3 points] Consider a hard drive with 1000 (0-999) cylinders which has a queue of 50 pending requests. If first 49 out of 50 requests are for cylinders less than 100, and the last (50^{th}) request is for cylinder 990, which of the following scheduling algorithm will serve the 50^{th} request in shortest wait time
    a. FCFS
    b. SSTF
    c. SCAN
    d. C-SCAN

Part III: Answer the following questions

17. [3 points] Explain in 2-3 sentences: How is the modify (dirty) bit useful in finding page replacement?

    The modify bit can be used to reduce the overhead of page transfers. When a page is chosen to be replaced the modify bit is checked to see if we need to write the page to the disk first before replacing it.

18. [3 points] Explain the write bottleneck problem of RAID 4 and how RAID 5 solves the write bottleneck problem.

    In RAID 4 since each disk operates independently throughput is limited to single disk level performance. Therefore, data access is all focused on a single parity disk because parity is not striped across multiple disks. RAID 5 solves this issue with the parity strip being across all the disks.

19. [3 points] Explain in 2-3 sentences: What is the difference between symbolic (soft) and nonsymbolic (hard) links? Describe one disadvantage of both.

    A soft link points to another file in a file system. A hard link points to the i-node/file control block of a file.

    Soft Link: slow and deletion of the shared file causes the soft link to point at nothing.
    Hard Link: can't point to the directories and files in other file systems.

20. [3 points] What is global and local page replacement? Describe one disadvantage of both.

In global page replacement, a process will select a victim from the set of all frames. In local page replacement, a process can only select a victim from its own set of frames.

Global: a process can steal a frame from another, potentially causing another page fault in the process that was stolen from, which leads to extended execution time.
Local: it is hard to determine the amount of pages a single process will need, therefore sometimes the process won't have as many to be fully efficient and the OS has to keep track of all these pages.

21. [20 points] Consider the following page reference string

2, 4, 6, 4, 2, 5, 7, 6, 4, 1, 2, 1, 6, 1

Assume that the process has 3 frames all of which are initially empty. For each of the following page replacement algorithm, how many page faults occur? Show your work with which pages are in frames at each page reference of the string. [You will get no points if you do not show your work and simply write the number of page faults]

a. [4 points] FIFO

• 2	• 5	• 1	
• 4	• 7	• 2	• 9 page faults
• 6	• 4	• 6	

b. [4 points] Optimal

• 2	• 5	• 7	• 1	
• 4			• 2	• 7 page faults
• 6				

c. [4 points] Least recently used (LRU)

• 2	• 6	• 2		
• 4	• 7	• 1		• 10 page faults
• 6	• 5	• 4	• 6	

d. [4 points] Second chance algorithm

• 2	• 7	• 1		
• 4	• 6	• 2		• 10 page faults
• 6	• 5	• 4	• 6	

e. [4 points] Enhanced second change algorithm. Assume that all page references to pages 1 and 6 modify the page. References to the rest of the pages (2, 4, 5, 7) do not modify the page.

• 2	• 7	• 1		
• 4	• 6			• 9 page faults
• 6	• 5	• 4	• 2	

22. [15 points] Consider a system in which there are three processes (A, B and C) running. Page references made by each process are shown below along with the time. Assume that your operating system is using working set model for page replacement. Answer the following questions.

Time	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12	t13	t14	t15	t16	t17	t18
A	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
B	4	5	6	7	4	4	5	7	6	8	9	12	13	9	8	13	12	12
C	18	19	19	18	19	18	19	18	19	18	19	17	18	19	17	19	18	17

a. [3 points] If the working set window for each process contains the last = 8 page references, what is the maximum size of working set for each process? Show which pages are in the working set when the size is maximum for each process.

Process A: WSS = 3
Process B: WSS = 8
Process C: WSS = 3

b. [7 points] Assume that the operating system has a total of 11 frames in the main memory. Considering that each process uses working set window of last = 8 page references, will there be thrashing at any point (from t1 to t18)? If yes, at what exact time (t?) the thrashing will start? Show your work including the size of working set and which pages are there in each process's working set when/if thrashing occurs.

Thrashing will start at t12.

At t11:

Process A: 3
Process B: 6
Process C: 2
Summation of WSS = 11, Total frames = 11 → 11 = 11 no thrashing.

At t12:

Process A: 3
Process B: 7
Process C: 3
Summation of WSS = 13, Total frames = 11 → 13 > 11 thrashing begins.

c. [5 points] If you want to ensure that there is no thrashing in executing processes A, B and C as shown above, what can be the maximum possible value of □? Assume that □ is same for all three processes.

□ = 6 to ensure there is no thrashing for the above scenario.

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23. [10 points] Suppose that a disk drive has 5000 cylinders, numbered 0 to 4999. The drive is currently serving a request at cylinder 2150, and the previous request was at cylinder 1805. The queue of pending requests is:

2069, 1212, 2296, 2800, 544, 1618, 356, 1523, 4965, 3681

For each of the disk scheduling algorithm listed below, what is the total distance (in cylinders) that the disk arm moves to satisfy all the pending requests. Also, show the order in which the requests will be served in each scheduling algorithm. Show your work.

a. [1 point] FCFS

2150 → 2069 → 1212 → 2296 → 2800 → 544 → 1618 → 356 → 1523 → 4965 → 3681

Total head movement = 13,011 cylinders

b. [1 point] SSTF

2150 → 2069 → 2296 → 2800 → 3681 → 4965 → 1618 → 1523 → 1212 → 544 → 356

Total head movement = 7,586

c. [2 point] SCAN

2150 → 2296 → 2800 → 3681 → 4965 → 4999 → 2069 → 1618 → 1523 → 1212 → 544 → 356

Total head movement = 7,492

d. [2 point] C-SCAN

2150→2296→2800→3681→4965→4999→0→356→544→1212→1523→1618→2069

Total head movement = 9,917

e. [2 point] LOOK

2150 → 2296 → 2800 → 3681 → 4965 → 2069 → 1618 → 1523 → 1212 → 544 → 356

Total head movement = 7,424

f. [2 point] C-LOOK

2150 → 2296 → 2800 → 3681 → 4965 → 356 → 544 → 1212 → 1523 → 1618 → 2069

Total head movement = 9,137

24. [8 points] In a certain computer system, the logical address is represented by 48 bits. The page size is 1 MB (2^{20} bytes). The system's physical address is represented by 32 bits. Each page table entry is 4 bytes.

a. [4 points] Assuming a single-level conventional page table, how many bits are we going to have in the "page number" field? In the offset field? What is the total size of the page table? Show your work.

Offset = size of page, 2^{20}, so 20 bits
Bits in page number = logical address – offset = 48 – 20 = 28 bits
of the pages = logical address space/page size = $2^{48}/2^{20} = 2^{28}$
Size of page table = # of pages * page table entry size = $2^{28} * 4 = 2^{30}$ or 1 GB of memory

b. [4 points] Assuming a two-level page table where each inner page table is also 1 MB, how many bits do we have in the "p1" field? in the "p2" field? in the offset field? What is the total size of all the page tables in this system? Show your work.

# of blocks = page table size/page size = $2^{30}/2^{20} = 2^{10}$ or 1024 blocks
P1 bits = entries pointing to each block, 2^{10}, so 10 bits
# of Descriptors per block = page size/page table entry size = $2^{20}/4 = 2^{18}$
P2 bits = # of Descriptors per block, 2^{18}, so 18 bits

2 ways to calculate Offset:
Offset = size of page, 2^{20}, so 20 bits **OR** = logical address – (P1 + P2) = 48 – (10 + 18) = 20 bits

Size of page table = # of blocks * # of descriptors * page size = $2^{10} * 2^{18} * 2^{20} = 2^{48}$ or 262,144 GB

25. [7 points] For a computer, you are given the following parameters:
    - Effective memory access time in the absence of paging (computed by considering the main memory access time and the L1-cache): 90 ns
    - TLB access time: 5 ns
    - TLB hit ratio: 95 %

    Assume that the page table entries are not stored in the L1-cache. There is NO virtual memory.

    a. [3 points] Assuming a single-level page table, what would be the effective memory access time with paging enabled? Show your work.

    EAT = 0.95 * 95 + 0.05 * (95 + 90) = 99.5 ns

    b. [4 points] Assuming a 2-level page table, what would be the effective memory access time with paging enabled? Show your work.

    EAT = 0.95 * 95 + 0.05 * (95 + 90 + 90) = 104 ns