**CS 6025, Operating Systems**

**Homework 2**

1. (5 points) What is segmentation for?

*Segmentation allows a process to have many virtual address spaces. The purpose is to break program data into logically independent spaces to aid sharing and protection.*

2. (10 points) For each of the following decimal virtual addresses, compute the virtual page number and offset for a 4-KB page (and for an 8-KB page: 20000, 32768, 60000).

*4k:*

|  |  |  |
| --- | --- | --- |
|  | *Page number* | *offset* |
| *20000* |  |  |
| *32768* |  |  |
| *60000* |  |  |

*Here is just an example: If page is 8k:*

|  |  |  |
| --- | --- | --- |
|  | *Page number* | *offset* |
| *20000* |  |  |
| *32768* |  |  |
| *60000* |  |  |

*4 KB = 212 B = 4096 B  
8 KB = 213 B = 8192 B*

*For virtual address 20000:*

1. *4-KB page: 20000/4096=4, remainder 3616. Virtual page number is 4, offset is 3616.*
2. *8-KB page: 20000/8192=2, remainder 3616. Virtual page number is 2, offset is 3616.*

*For virtual address 32768:*

1. *4-KB page: 32768/4096=8, remainder 0. Virtual page number is 8, offset is 0.*
2. *8-KB page: 32768/8192=4, remainder 0. Virtual page number is 4, offset is 0.*

*For virtual address 60000:*

1. *4-KB page: 60000/4096=14, remainder 2656. Virtual page number is 14, offset is 2656.*
2. *8-KB page: 60000/8192=7, remainder 2656. Virtual page number is 7, offset is 2656.*

3. (5 points) Given a two-level page table with 4-KB pages and. Assume that each level uses 10 bits. What would be the virtual address if PT1=2, PT2=3, offset=5?

*4 KB = 212 B, so the offset has 12 bits*

|  |  |  |
| --- | --- | --- |
| *10* | *10* | *12* |

*Virtual address: 2×222+3×212+5=8400901*

4. (5 points) Describe how does the clock page replacement algorithm work?

*The clock page replacement algorithm is an implementation of the second-chance page replacement algorithm. All pages in memory form a circular list and a clock hand moves clockwise to point to pages. When a page fault occurs, the page the hand is pointing to is inspected. If the page’s reference bit is zero, the page is evicted. Otherwise, the hand clears the page’s reference bit and advances to the next page until an eviction candidate is found.*

5. (5 points) What are external and internal fragmentations?

*External fragmentation occurs when the free memory space is enough for memory allocation but is not contiguous so it cannot be used. It is the result of frequent memory allocations and de-allocations.*

*Internal fragmentation refers to the extra space left inside a block of memory.*

6. (10 points) Consider a system with 3 physical frames of memory that is given the following page memory reference sequence: 1, 3, 6, 7, 1, 3, 6, 7, 1, 3, 6, 7. What is the number of page faults that would occur for each of the following page replacement algorithms?

a. An optimal page replacement algorithm

b. FIFO

b. LRU

*Note: The below figure is from Jose Fabregas:*

*a. Optimal has 6 page faults*

*A picture containing sky

Description automatically generated*

*b. FIFO has 12 page faults (use similar to queue to calculate)*

*A close up of a screen

Description automatically generated*

*c. LRU has 12 page faults (use similar to stack to calculate)*

A picture containing indoor, sky

Description automatically generated

7. (5 points) Compare the following free memory management algorithms: first-fit, best-fit, and worst-fit.

*First-fit: allocate the first hole that is big enough.*

*Best-fit: allocate the smallest hole that is big enough.*

*Worst-fit: allocate the largest hole, so that the new hole will be big enough to be useful.*

8. (5 points) Why do not we store information in the process address space? In other words, why we need files in OS?

*Size is limited to size of virtual address space*

*May not be sufficient for airline reservations, banking, etc.*

*The data is lost when the application terminates*

*Even when computer doesn’t crash!*

*Multiple process might want to access the same data*

*Imagine a telephone directory part of one process*

9. (5 points) What are memory-mapped files and what are the advantages.

*A memory-mapped file is a part of* [*virtual memory*](http://en.wikipedia.org/wiki/Virtual_memory)*, which has been mapped to some portion of a file or file-like resource.*

*The advantages of memory-mapped files are improved I/O performance and avoidance of kernel to user data copying.*

10. (10 points) Discuss the advantages and disadvantages of contiguous allocation, linked list allocation, and FAT.

*Contiguous allocation: store each file as a contiguous run of disk blocks. First advantage is that it is simple to implement, only starting location and length are required. Second, the read performance is excellent because the entire file can be read from the disk in a single operation, only one seek is needed. The drawback is that the disk can become fragmented, wasteful of space, files cannot grow.*

*Linked list allocation: each file is a linked list of disk blocks, blocks may be scattered anywhere on the disk. Pros: no space is lost due to disk fragmentation; also, it is sufficient for the directory entry to only store the disk address of the first block. Cons: random access is extremely slow, to get block n, OS has to start at beginning and read the n-1 blocks prior to it, doing so many reads will be painfully slow.*

*FAT: a table in memory with the pointer word of each disk block. Pros: the entire block is available for data, random access is much easier. Cons: the entire table must be in memory all the time to make it work, it does not scale well to large disks.*

11. (5 points) Why the index allocation (e.g., i-node) requires much less space than FAT?

*Only the i-nodes of the opened files need to be in memory and the memory requirement is independent from the size of the hard drive.*

12. (5 points) What is symbolic linking?

*A symbolic link or a soft link is a new file containing the path of the linked file.*

13. (5 points) Give two examples (each) of block devices and character devices.

*Block devices: hard drive, CD.*

*Character devices: printer, mouse.*

14. (5 points) What is Direct Memory Access (DMA)?

*DMA controller has access to system bus independent of CPU*

*The I/O can transfer data to memory directly*

15. (15 points) Suppose that a disk drive has 300 cylinders, numbered 0 to 299. The drive is currently serving a request at cylinder 143, and the previous request was at cylinder 15. The queue of pending requests, in FIFO order, is 86, 147, 291, 18, 95, 151, 12, 175, 30. Starting from the current head position, what is the total distance (in cylinders) that the disk arm moves to satisfy all the pending requests, for each of the following disk-scheduling algorithms?

a. FCFS

b. SSF

c. Elevator algorithm

*Note: The below figure is from Jose Fabregas:*

*a. FCFS*

*143 86 147 291 18 95 151 12 175 30*

*Total distance: 57+61+144+273+77+56+139+163+145=1115*

*A close up of a whiteboard

Description automatically generated*

*b. SSF*

*143 147 151 175 95 86 30 18 12 291*

*Total distance: 4+4+24+80+9+56+12+6+279=474*

*A close up of a whiteboard

Description automatically generated*

*c. Elevator algorithm*

*143 147 151 175 291 95 86 30 18 12*

*Total distance: 4+4+24+116+196+9+56+12+6=427*

A close up of text on a white surface

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