Amrita School of Engineering, Amritapuri Campus.
15CSE213: Operating Systems
Tutorial 1 on Memory Management
Memory Allocation

Opening Date	Due Date
21/04/2020	24/04/2020

Memory Allocation Overview

- Contiguous Memory Allocation Techniques
  - Fixed -size partitioning
  - Variable size partitioning
- Non- Contiguous Memory Allocation Techniques
  - Paging
  - Segmentation

I. Contiguous Memory Allocation

1. Differentiate internal fragmentation with external fragmentation. Which fragmentation can happen in the following memory allocation schemes? Justify.
   a. Contiguous memory allocation with fixed size partitioning
   b. Non-contiguous memory allocation with fixed size partitioning
2. Explain compaction.
3. Consider six memory partitions of sizes 150KB, 390KB, 100KB, 450KB, 30KB and 270KB (in order). How would the following algorithms place the following processes P1, P2, P3, P4, P5 and P6 arriving in order whose respective sizes are as follows 98KB, 130KB, 360KB, 20KB, 420KB and 170KB.
   a. First Fit
   b. Best-Fit
   c. Worst Fit

   Also mention the amount of internal fragmentation and external fragmentation (if any) occurred in each of the above allocation algorithms.
4. Consider three memory partitions of sizes 120KB, 300KB, and 70KB (in order). How would the following algorithms place the following processes P1, P2 and P3 arriving in order whose respective sizes are as follows 60KB, 190KB and 360KB.
   a. First Fit
   b. Best-Fit
   c. Worst Fit

   Also mention the amount of internal fragmentation and external fragmentation (if any) occurred in each of the above allocation algorithms.
   (Hint: For Questions 3 & 4, you can watch the following video, if required)
   https://www.youtube.com/watch?v=YcX-awpW9yc

II. Non-Contiguous Memory Allocation

For Main Memory (Physical address space divided into Frames)

- Physical Address Space = Size of main memory
- Size of main memory = Total number of frames x frame size
- Frame size = Page size
- If number of frames in main memory = 2^X, then number of bits required to represent the frame number = X bits
- If Page size = 2^X Bytes, then number of bits in page offset = X bits
- If size of main memory = 2^X Bytes, then number of bits in physical address = X bits

For Process (Logical/virtual address space divided into Pages)

Virtual Address Space = Size of process

- Number of pages the process is divided = Process size / Page size
- If process size = 2^X bytes, then number of bits in virtual address space = X bits

For Page Table:

Note : Page Table stores the frame numbers in which each of the pages of a process is stored in main memory

- Size of page table = Number of entries in page table x Page table entry size
    - Number of entries in page table = Number of pages the process is divided
    - Page table entry size = Number of bits in frame number + Number of bits used for optional fields if any

NOTE:

- In general, if the given address consists of 'n' bits, then using 'n' bits, 2^n locations are possible.
- Then, size of memory = 2^n x Size of one location.
- If the memory is byte-addressable, then size of one location = 1 byte.
- Thus, size of memory = 2^n bytes.
- If the memory is word-addressable where 1 word = m bytes, then size of one location = m bytes.
- Thus, size of memory = 2^n x m bytes.

PRACTICE PROBLEMS BASED ON PAGING AND PAGE TABLE-

Note:

1 KB = 2^{10} bytes

1 MB = 2^{20} bytes

1 GB = 2^{30} bytes

A. Calculate the size of memory if its address consists of 22 bits and the memory is 2-byte addressable.

Solution-

We have-

- Number of locations possible with 22 bits = 2^{22} locations
- It is given that the size of one location = 2 bytes

Thus, Size of memory

= 2^{22} x 2 bytes

= 2^{23} bytes

= 8 MB

B. Calculate the number of bits required in the address for memory having size of 16 GB. Assume the memory is 4-byte addressable.

Solution-

Let 'n' number of bits are required. Then, Size of memory = 2^n x 4 bytes.

Since, the given memory has size of 16 GB, so we have-

2^n x 4 bytes = 16 GB

2^n x 4 = 16 GB

2^n x 2^2 = 2^{34}

2^n = 2^{32}

∴ n = 32 bits

C. Consider a system with byte-addressable memory, 32 bit logical addresses, 4 kilobyte page size and page table entries of 4 bytes each. The size of the page table in the system in megabytes is _____.

Solution-

Given-

- Number of bits in logical address = 32 bits
- Page size = 4KB
- Page table entry size = 4 bytes

Process Size-

Number of bits in logical address = 32 bits

Thus,

Process size

$= 2^{32}$ B

= 4 GB

Number of Entries in Page Table-

Number of pages the process is divided

= Process size / Page size

= 4 GB / 4 KB

$= 2^{20}$ pages

Thus,

Number of entries in page table = 2^{20} entries

Page Table Size-

Page table size = Number of entries in page table x Page table entry size

$= 2^{20}$ x 4 bytes

= 4 MB

D. Consider a machine with 64 MB physical memory and a 32 bit virtual address space. If the page size is 4 KB, what is the approximate size of the page table in MB?

a. 16 MB
b. 8 MB
c. 2 MB
d. 24 MB

Solution-

Given-

- Size of main memory = 64 MB
- Number of bits in virtual address space = 32 bits
- Page size = 4 KB

We will consider that the memory is byte addressable.

Here the page table entry size (ie no; of bits required to represent a frame number) was not provided. Instead the details about the physical memory is given.

Number of Frames in Main Memory-

Number of frames in main memory

= Size of main memory / Frame size

= 64 MB / 4 KB (note: Frame size should be same as page size)

= 2^{26} B / 2^{12} B

= 2^{14}

Thus, Number of bits to represent frame number = 14 bits

ie, the page table entry size = 14 bits

Process Size-

Number of bits in virtual address space = 32 bits

Thus,Process size

= 2^{32} B

= 4 GB

Number of Entries in Page Table-

Number of pages the process is divided

= Process size / Page size

= 4 GB / 4 KB

= 2^{20} pages

Thus, Number of entries in page table = 2^{20} entries

Page Table Size-

Page table size

= Number of entries in page table x Page table entry size

= Number of entries in page table x Number of bits in frame number

= 2^{20} x 14 bits

= 2^{20} x 16 bits (Approximating 14 bits ≈ 16 bits)

= 2^{20} x 2 bytes

= 2 MB

Thus, Option (C) is correct.

E. In a virtual memory system, size of virtual address is 32-bit, size of physical address is 30-bit, page size is 4 Kbyte and size of each page table entry is 32-bit. The main memory is byte addressable. Which one of the following is the maximum number of bits that can be used for storing protection and other information in each page table entry?

a. 2
b. 10
c. 12
d. 14

Solution-

Given-

- Number of bits in virtual address = 32 bits
- Number of bits in physical address = 30 bits
- Page size = 4 KB
- Page table entry size = 32 bits

Size of Main Memory-

Number of bits in physical address = 30 bits

Thus,

Size of main memory

$= 2^{30}$ B

= 1 GB

Number of Frames in Main Memory-

Number of frames in main memory

= Size of main memory / Frame size

= 1 GB / 4 KB

$= 2^{30}$ B / 2^{12} B

$= 2^{18}$

Thus, Number of bits in frame number = 18 bits

Number of Bits used for Storing Other Information-

Maximum number of bits that can be used for storing protection and other information

= Page table entry size – Number of bits in frame number

= 32 bits – 18 bits

= 14 bits

Based on the above practice questions solve the following questions.

5. Why are page sizes always in powers of 2?
6. Consider a logical address space of 8 pages of 1024 words each, mapped onto a physical memory of 32 frames. How many bits are there in the physical address and logical address respectively?
7. Calculate the number of pages and number of frames present in a system having 6-bit logical address space and 7-bit physical address space and page size is 8 words.
8. Consider the Page map table given below:

Page	**0**	**1**	**2**	**3**
Frame	**5**	**2**	**7**	**3**

If the frame size is 1024, What is the physical address associated with the logical address. [Logical address notation <*a, b*> implies *a* is the page number and *b* is the offset]

a) <2, 85> b) <3,1635>

(Hint: For Questions 6 & 7, you can also watch the following video, if required)
https://www.youtube.com/watch?v=xAvC-MJ_Sz8

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