

Assignment - II

1. Address translation with multiple processes.

In modern systems with multiprogramming, multiple processes coexist in memory. Each process is given a logical (virtual) address space, while the actual data resides in physical memory (RAM). The translation is managed by Memory management Unit (mmu) with help of page tables.

Steps:

- (i) Logical Address Generation
- (ii) mmu translation via page table
- (iii) Physical Address Formation

(B) Access to Physical Memory

2. Memory layout with fragmentation

- Internal Fragmentation: Fixed partitions waste space inside blocks.

e.g. Block = 8 KB, Process needs 6 KB \rightarrow 2 KB wasted

- External Fragmentation: free memory is scattered.

e.g. layout:

10 mB	Free 5 mB	20 mB	Free 3 mB	15 mB	Free 6 mB
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Modern OS solutions (beyond compaction)

- Paging: removes external fragmentation
- Segmentation + Paging: Reduces both types
- Buddy system: split/merges memory in powers of two
- slab allocation: Efficient kernel memory use
- Virtual memory: Non-contiguous allocation avoids external fragmentation

3. Paging-based memory Allocation model.

- memory is divided into fixed size pages.
- Each process has a page table mapping virtual pages
→ physical frames.
- MMU + TLB handle fast translation; on TTB miss,
- eliminates external fragmentation (by free frame reclamation)

Trade-offs

- memory overhead: large page tables per process;
mitigates with multi-level tables.
- Speed: TLB hits are fast; misses (page fault) slow down execution.
- No external fragmentation; but small internal frag.
- Huge pages: reduce TLB pressure (faster) but increase internal waste.

4. When an OS manages a virtual memory, it works closely with the hardware to make sure processes run in isolated, protected, and efficient environments.

Interaction b/w Hardware and OS in virtual memory

- i) virtual to physical Address translation.
- ii) Page table
- iii) Translation lookaside Buffer (TLB)
- (iv) Memory protection
- (v) Page faults and demand paging
- (vi) Hardware support for isolation

Key Hardware Structures

- MMU : handles address translation
- Page tables : OS managed structures mapping virtual pages to physical frames
- TLB : hardware cache for fast translations.

5. virtual address size = 16 bits

page size = 1 KB = 1024 bytes = 2^{10} bytes

Page Table entry (PTE) size = 2 bytes

(a) virtual add = 16 bits total

Page size = 2^{10} → 10 bits used for offset within a page

Remaining bits for page no = $16 - 10$
= 6 bits

So, page no. field = 6 bits

page offset field = 10 bits

no. of virtual pages = $2^6 = 64$ virtual pages

(b) Each virtual page needs one entry in page table

no. of entries = 64

Each entry = 2 bytes

Page total size = $64 \times 2 = 128$ bytes

PART-B

6. Memory Allocation Simulation

A system has 1000 KB of free memory.

Process	Size (KB)
P ₁	212
P ₂	417
P ₃	112
P ₄	426

Using first-fit, best-fit and worst-fit

first-fit

$$\text{Start} = 1000 \text{ KB}$$

Place P_1 (212 KB) \rightarrow remaining = $1000 - 212 = 788 \text{ KB}$

Place P_2 (417 KB) \rightarrow remaining = $788 - 417 = 371 \text{ KB}$

Place P_3 (112 KB) \rightarrow remaining = $371 - 112 = 259 \text{ KB}$

Try P_4 (426 KB) \rightarrow $259 \text{ KB} < 426 \text{ KB} \Rightarrow$ can't place

Result : Allocated P_1, P_2, P_3 ; free = 259 KB

Best-fit : Same sequence here (only one at each step)
 \rightarrow 259 KB leftover (P_4 unallocated)

Worst-fit : same result \rightarrow 259 KB leftover

Conclusion : All three produces identical results for this allocation. 259 KB used

- P_4 not placed.

7. Page reference string :

7, 0, 1, 2, 0, 3, 0, 4, 2, 3, 0, 3, 2 and [3 frames]

FIFO

Ref	7	0	1	2	0	3	0	4	2	3	0	3	2
F_1	7	7	7	2	2	2	2	4	4	4	0	0	0
F_2	-	0	0	0	0	3	3	3	2	2	2	2	2
F_3	-	-	1	1	1	1	0	0	0	3	3	3	3
Fault	F	F	F	F	H	F	F	F	F	F	H	H	H

Total FIFO page faults = 10

Optimal (Belady's algo)

R.C.F	F ₁	F ₂	F ₃	Fault
7	7	-	-	F
0	7	0	-	F
1	7	0	1	F
2	2	0	1	F
0	2	0	1	H
3	2	0	3	F
0	2	0	3	H
4	4	2	0	F
2	4	2	0	H
3	4	2	3	F
0	0	2	3	F
3	0	2	3	H
2	0	2	3	H

Total Optimal page faults = 7 (min-possible)

LRU (Least Recently Used)

R.C.F	7	0	1	2	0	3	0	4	2	3	0	3	2
F ₁	7	7	7	2	2	2	2	4	4	4	4	0	0
F ₂	-	0	0	0	0	0	0	0	0	0	3	3	3
F ₃	-	-	1	1	1	3	3	3	2	2	2	2	2
fault	F	F	F	F	F	H	F	H	F	F	F	H	H

Total LRU page faults = 9

Ordering (Best → Worst) is :

Optimal (7) < LRU (9) < FIFO (10).

8. Disk write time = 10 ms per page

memory write time = 100 ns per page

replaced pages that are dirty = 30 %.

no. of replaced pages = 1000

(a) Additional time overhead due to dirty pages
when replacing 1000 pages

$$\text{dirty pg.s} = 0.30 \times 1000 = 300$$

$$\text{disk time} = 300 \times 10 \text{ ms} = 3000 \text{ ms} = 3 \text{ seconds}$$

$$\text{memory time} = 1000 \times 100 \text{ ns} = 100,000 \text{ ns} = 0.1 \text{ ms}$$

$$\text{Total time spent} = \text{disk time} + \text{mem}$$

$$\text{So, additional overhead} = 3 \text{ sec.}$$

$$\text{total (disk + mem)} = 3000 \text{ ms} + 0.1$$

$$= 3000.1 \text{ ms}$$

$$\approx 3 \text{ sec.}$$

(b) Proposed optimization to reduce this overhead.

Best single practical optimization:-

Background pre-clearing + prefer clean victims.

Two linked ideas that are commonly used together:

- page-cleaner daemon (background write-back)

- Clean first victim selection (enhanced clock / "modified list")

9. Autonomous Vehicle Case Study :

(a) Working set model + replacement policy

- OS tracks recent active pages per task.
- for object detection : Allocates stable working set
- for environment : Allows flexible replacement as it adapts to available memory.

(b) Memory Allocation Strategy

- Use priority-based dynamic allocation
- Real-time responsiveness ensured by working set + real time schedule.